BULLETIN No. 25. V. P. P.—78.

U. S. DEPARTMENT OF AGRICULTURE,

DIVISION OF VEGETABLE PHYSIOLOGY AND PATHOLOGY.

B. T. GALLOWAY, Chief.

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SOME DISEASES OF NEW ENGLAND CONIFERS:

A PRELIMINARY REPORT.

BY

HERMANN VON SCHRENK,

Instructor in Botany, Henry Shaw School of Botany,

Special Agent, Division of Vegetable Physiology and Pathology.

WASHINGTON:

GOVERNMENT PRINTING OFFICE.

1900.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Division of Vegetable Physiology and Pathology,
Washington, D. C., August 8, 1900.

Sir: I respectfully transmit herewith a paper prepared by Dr. Hermann von Schrenk, special agent of this Division, on Some Diseases of New England Conifers. The investigations described were carried on in cooperation with the Division of Forestry of this Department and the Shaw School of Botany, of St. Louis, Mo., and are of special interest at this time, in view of the increasing demand for information on forest problems. I respectfully recommend that the paper be published as Bulletin No. 25 of this Division.

Dr. von Schrenk desires acknowledgment on his behalf to the following persons for courtesies shown him and assistance rendered in his work: Mr. Austin Cary, of the Berlin Mills Company; Professor Harvey, of Orono, Me.; Mr. S. Boardman, of the Bangor Commercial; and Mr. Cram, of the Bangor and Aroostook Railroad.

Respectfully,

B. T. Galloway,
Chief of Division.

Hon. James Wilson,
Secretary of Agriculture.

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SOME DISEASES OF NEW ENGLAND CONIFERS.

INTRODUCTION.

NECESSITY FOR STUDYING THE DISEASES OF FOREST TREES.

Very little attention has been paid to the study of diseases of forest trees in the United States up to this time, and the reasons are obvious enough. Up to within a few years the supply of standing timber of all kinds has been so large that a few diseased trees, more or less, scattered over wide areas were of little account. The lumberman cut down the sound trees and paid no attention to such as he recognized to be of inferior value. The situation has changed within the last decades, and a wide-felt demand has arisen among all classes of people for a more economical and rational treatment of the existing forest lands, and for reestablishing forests on denuded areas. In the primeval forest the trees diseased because of fungous or insect attack were ignored. They were few in comparison with sound trees, and the price of a single tree was very low. At the present time, with a marked appreciation in the value of timber, the agencies which injure trees for timber are of more immediate interest to the owners of woodlands. At this time the extent to which insects and fungi destroy trees can only be guessed at. Their work of destruction goes on silently here and there in the forest, and does not attract the attention of the casual observer as do careless lumbering or forest fires. If the dead and dying trees in a forest could be collected, they would represent a considerable percentage of the total forest. Forest fires are already not so common as they used to be, and the lumberman of to-day is beginning to understand that more can be realized from a given forest tract by rational treatment than by indiscriminate cutting. Insects and fungi, and other harmful agencies of less importance, are being studied with the aim of arriving at a more complete understanding of their manner of working.

From its first growth until it falls a tree is subject to attacks of a large number of insects and fungi, often resulting in stunted growth or death. In many cases the injury is to the wood alone; the diseased tree may remain standing for many years, and may be useful as a shade

tree, but its value for timber has been destroyed. Besides the insects and fungi, diseases which may be characterized as physiological are not uncommon. They may be due to an insufficient supply of light, heat, water, or food, etc. Often insects and fungi act in conjunction with other unfavorable agencies, and it then becomes a matter of considerable difficulty to ascertain the true cause of the disease. The present paper deals only with diseases due to fungi.

The mycelia of fungi attack living trees as well as dead ones. When on living trees they grow either in the living parts, the roots, leaves, bark, or newer wood cells, or in the dead parts, the heartwood of the roots, trunk, and branches. The character of the injury which the mycelium causes depends much upon its place of growth, whether on the leaves or within the wood. Injury to the leaves may often be very great, as is the case with fungi like the *Erysipheæ*, *Uredineæ*, *Exoascæ*, and others. The injury caused by those which grow in the living bark or cambium, like the species of *Nectria*, for instance, is very large. A large class of fungi flourishes within the heartwood of trees, growing into it through a branch or some wound, and in some cases through the roots. The effect of their growth is to destroy the heartwood, filling it with holes or turning it to a brittle substance which has none of the properties of ordinary wood. These changes weaken the trunk, and at some period or other the tree is broken by the wind. Those forms which enter through the roots may kill the latter first, and thus cause a tree to fall. The wood is then rapidly destroyed by a large variety of fungi and insects. It is therefore to the interest of the forester who grows trees for their wood to determine what fungi so affect the trees as to render the wood unfit for lumbering purposes.

In Europe, where forests have been grown for many years, the importance of understanding the diseases of forest trees has long been recognized, as is well shown by the works of Hartig, Tubeuf, Marshall Ward, Frank, Nypels, and others. These show that it is possible to prevent the growth of many of these fungi by destroying their fruiting bodies, and, in general, by bringing about conditions unfavorable to their growth and development. In order that this may be properly and successfully done, it is first necessary to know what the destructive fungi are and where and how they live. It was with this end in view that the writer spent several months during the year 1899 in the forests of Maine. A preliminary survey was made of the forests of that State, and the results are here presented in preliminary form.

WHERE THE INVESTIGATIONS REPORTED WERE MADE.

The region about Houlton in Aroostook County was first visited, then the territory north of Moosehead Lake, and during September the region about the Rangeley Lakes. A large part of the summer was spent on the coast at Linekin (near Boothbay Harbor, Maine), where

the extensive spruce groves of both older and younger trees presented excellent opportunities for a study of the commoner forms. Collections of wood and fungi were made at all points visited. The basis of this report consists of field notes made in the regions visited, together with brief descriptions of the various forms of diseased wood. When the opportunities permitted, inoculations were made, by means of spores and mycelia, the results of which will not be apparent for many years.

PREVIOUS WORK ON DISEASES OF TREES.

Practically no work has so far been done on the diseases which affect the woody parts of the forest trees of the Northeastern States. Many descriptions have been published of the fungi which grow on these trees, but these deal mostly with the fruiting portion of these fungi and but rarely with the effects which they bring about in their substratum. Nearly all of the fungi of this class have been very thoroughly studied by Hartig[1] in Germany, and many of the conclusions of the present paper correspond with the results which he obtained. His studies, however, were confined to the effects of the fungi on the forest trees of Germany. The only notes on the forest fungi of America which the writer was able to find are those in Sargent's Silva of North America.[2] A number of the commoner fungi are there referred to briefly. The majority of these, however, are leaf fungi, viz, *Dasyscypha willkommii* R. Hartig, "said to occur in the United States, etc.," the various species of *Peridermium*, and a few others.

The catalogues of floras report many of the fungi herein noted, but the mere record of the occurrence of a fungus at one or more localities is of so little value in this connection that it was not considered worth while to present even an enumeration of them here.

KINDS OF FUNGI GROWING ON FOREST TREES AND THEIR RELATION TO FOREST PROBLEMS.

Of the fungi found growing on the wood of the coniferous trees but a small number bring about changes which completely destroy the wood. Many fungi grow on the bark of a dead tree or their mycelia penetrate into the living bark, where they flourish, but go no deeper. Others, again, grow in the bark and sapwood of trees after the latter have died, and in so doing destroy these parts. A third class grows in the heartwood only, or in heartwood, sapwood, and bark, whether the trees are alive or dead. Several of the last-mentioned class attack living trees and slowly bring about changes which ultimately result in

[1] Hartig, R. Zersetzungserscheinungen des Holzes der Nadelholzbäume und der Eiche. 1878.

[2] Sargent, C. S. Silva of North America. 12:5, 26. 1898.

death. Others grow within the heartwood, in which case the tree may remain alive as long as the trunk is strong enough to uphold the crown of branches. Some of these fungi can grow both as saprophytes, i. e., on dead wood, or as facultative parasites on living trees. In the following only those fungi are considered which so destroy the wood of the trees as to render it unfit for lumbering purposes.

The fungi to be described all belong to the *Polyporei*. Their sporophores form during the summer, and in several cases grow on during the winter months. They discharge their spores into the air in vast numbers, and these are carried to great distances by the wind. The spores germinate, under favorable conditions, in a wound or on the roots, and the mycelium makes its way into the inner parts of the tree, where it flourishes for a shorter or longer period, when the fruiting organ is again formed. The length of time which is required for the formation of the sporophores is variable, and is known for very few species. In some cases the sporophores grow only on the living trees; in other cases, again, they form for many years on the dead stumps or fallen trunks. Seasonal variations are to be met with. Some years, when it is exceptionally moist, the fruiting forms grow in great numbers, while during a dry summer very few are to be found.

EXTENT OF DESTRUCTION.

The amount of destruction which these fungi do is actually very large. As has been said, the casual observer does not note a dead tree here or there, but he is struck with the destruction wrought by forest fires. In certain localities the older trees are likely to become infected by one fungus or another, and it is a common saying of the lumberman that "the older trees are always rotten." If all the dead trees in a forest could be brought together, their number would truly be a surprise to lumbermen, the majority of whom have no appreciation of even the approximate destruction which is wrought in the forests in this way. Without extended cruisings it would be hazardous to make any more definite statement for the present than this: The number of dead and decayed trees is sufficiently large to represent a considerable loss in capital, and warrants making efforts to prevent the destruction of what would be valuable timber if harvested in time.

EXTERNAL EVIDENCES OF DECAY.

It is often a matter of considerable importance to recognize which trees in a forest have been attacked by fungi, so that these trees may be removed before they are completely destroyed and before there is any opportunity for the formation of sporophores. Trees which are in an advanced state of decay can usually be recognized by the fact that they have the fruiting organ of one or another fungus growing

on their roots, trunks, or branches. The lumberman of the present day naturally tries to avoid trees which are rotted, and his method of diagnosis consists in pounding the trunk to see whether it sounds hollow. Hollowness, however, is not always a sign of disease, as many trees are hollow at the base and sound above, and therefore satisfy the demands of the lumberman at least in part. A test in use all over the country is the presence of what are variously known as punks, conchs, punk knots, resin knots, etc. A punk is usually the sporophore of *Trametes pini*, or some other large hoof-shaped sporophore. The other terms are more often applied to swellings which occur at points where a dead branch stub is found on the tree. In diseased trees of Pine or Spruce the turpentine is driven from the wood by the action of the mycelium of this or that fungus, and passes on before it, up the heartwood of old branches and out through them, forming resinous lumps, which harden in contact with the air. These lumps occur at all heights on the trunk and increase in size from year to year. The accumulation of these resinous masses prevents the normal healing of the wound or healing over of the stub of the branch, and results in the formation of a marked protuberance at that point, commonly called a knot, with its various modifications. The turpentine often drips from such a spot or runs down the bark in small streams. It may be many years before the decomposition within the tree advances sufficiently to enable sporophores to form, and a system of prophylactic treatment must take into account phenomena such as these to aid in detecting diseases in their early stages. What has been said with reference to these resin accumulations applies particularly to fungi like *Trametes pini* (Brot.) Fr. and its form *abietis* Karsten, to *Polyporus schweinitzii*, and *Polyporus sulfureus*, and one or two others not yet definitely identified.

RELATION TO INSECT ATTACKS.

The nature of the fungus injury is often very obscure, and there are so many factors which have to be considered in tracing the nature of any one disease that the results of the present paper are but fragmentary, and it is very probable that they will be modified largely by future discoveries. The intimate relationship which exists between the attacks of insects on the one hand and fungi on the other must be pointed out. There are without doubt many fungi which find their way into the wood of trees through the holes which boring insects have made in the bark. The injury which the insect makes may be very slight, but it has opened the way for the action of the fungus, which may be very destructive. An example of this kind is to be found in that most curious of all the *Polyporei*, *Polyporus volvatus* Peck. This grows on the trunks of spruces which have been attacked by various species of boring beetles, notably species of Dendroctonus. These beetles bore through the bark into the cambium layer. The fungus enters through

these holes and grows in the sapwood of the tree, destroying it in a few months. Whether it grows there while the tree is still alive, and what its possible relations may be to the Dendroctonus, are problems yet to be solved. In many parts of the Maine woods every tree where the beetles had been or were still active was covered with the rounded fruiting organs of this Polyporus. (See Pl. I, fig. 2.) Their association with this Polyporus offers a promising field for study. The holes made by the beetles allow the spores of several other fungi to enter, notably those of *Polyporus pinicola*. These germinate and grow throughout the heartwood, rendering it worthless in a very short period.

The possible rôle which beetles and boring larvæ may play in carrying the spores of a fungus from one tree to another will be referred to below. These few instances will serve to show that it is all important that a study of the insect and fungus enemies of a tree should be made hand in hand.

There are grave inherent difficulties in determining the exact cause of death of a large tree, for there are many factors which may influence its growth so that the tree becomes weakened. There is a widespread opinion that insects or fungi will not attack an absolutely healthy tree, but that the latter must be more or less weakened before such an attack takes place. That this is not always the case need hardly be said, but the mere fact that a fungus is growing in the tree or an insect is at hand upon it is no positive proof that one or the other is the active agent in bringing about its death. Such evidence, particularly if oft repeated, will become very valuable when taken in conjunction with other proofs.

SCOPE OF THIS REPORT.

In the following a number of fungi will be described, together with the characteristic changes which their mycelia induce in the wood of the trees in which they grow. These fungi were found again and again, always associated with the forms of decay ascribed to them, and never was such decay found without the fungus in question, or without a mycelium from which the fruiting portion of the fungus developed. These fungi occurred on all coniferous forest trees, with few exceptions. Some of them started in the living trees and caused the heartwood to decay. They were found in large numbers destroying trees injured by insects, and on some tracts where fire had swept through the woods and had injured the bases of the tree trunks several of them had gained a foothold and had destroyed every tree thus injured. The principal ones met with were: *Polyporus schweinitzii* Fr.; *Polyporus pinicola* (Swartz) Fr., *Trametes pini* (Brot.) Fr. forma *abietis* Karsten; *Polyporus sulfureus* (Bull.) Fr.; and *Polyporus subacidus* Peck. A number of doubtful forms will be mentioned near the end of this report.

NEW ENGLAND FORESTS.

VEGETATIVE CONDITIONS.

The original forests of most of the New England States are gone. The White Pine, which at the advent of the white settler formed such a large part of the forests, is present in any large quantity only in the most inaccessible places and elsewhere as ripe timber only in isolated spots. The chief forest trees from the lumberman's standpoint are the Red Spruce and the White Spruce. Millions of feet of Red Spruce lumber are now being cut year after year in the States of Vermont, New Hampshire, and Maine. The time is not far distant, however, when the stand of spruce timber will be in a similar condition to that in which the White Pine is now.

The conditions which prevail in the forests of Maine and New Hampshire can be touched upon only in so far as they relate to the presence of and probable influence on the diseases which form the basis of this report. The forests are usually moist. The forest floor is covered with a large variety of mosses, which hold water very readily. Sphagnum covers many square miles. Springs and brooks are abundant everywhere. The annual rainfall, often very heavy during the spring and summer months, accounts for the general humidity of the air. Near the coast the fogs keep the woods moist for a large portion of the growing season. The summer season is usually comparatively short, but while it lasts very warm days are not uncommon. Warmth and humidity, chiefly the latter, are very influential in promoting the growth of many saprophytic as well as parasitic fungi.

Before describing the various fungi and their effects, it may be well to say something of the trees which are affected by these fungi.

RED SPRUCE.

Foremost among the coniferous trees of New England at the present time is the Red Spruce, *Picea rubens* Sarg. (*P. mariana* (Mill.) B. S. P., *P. nigra* Link). It is a tall, stately tree, which grows to be 70–80 feet (21–24 meters) high and 2–3 feet (0.6–1 meter) in diameter. It occurs all over northern New England, together with the Balsam Fir and White Pine. Sargent says of this tree:[1]

> Picea rubens, which is the principal timber spruce of the northeastern United States, and, with the exception of the White Pine, the most valuable coniferous timber tree of the region which it inhabits, produces light, soft, close-grained wood, which is not strong nor durable when exposed to the weather. It is pale, slightly tinged with red, with paler sapwood about two inches thick, and a satiny surface * * *. Now that the most valuable White Pine has been exhausted in the forests of the Northeastern States, the Red Spruce is their most important timber tree, and immense quantities of its lumber are manufactured every year from trees cut in Maine, New Hampshire, Vermont, and northern New York. * * *

[1] Sargent, C. S. Silva of North America. **12**:35. 1898.

The wood of the Red Spruce is used for construction, and thousands of trees of all sizes also find their way to the pulp mills for the manufacture of paper. During the summer of 1899 several large new mills were building in central Maine, one of which was expected to consume 300 tons of spruce wood daily. In a recent article in The Forester, Mr. Lyman, of the International Paper Company, discusses at length the use of this spruce for making pulp.

The tree is one of moderately slow growth. It reproduces itself well from seed, and grows up readily to replace the original stand of timber. In the forest, when growing in close stands, the lower branches die gradually and break off, leaving dead stubs which, in the case of larger branches, offer inviting spots for the entrance of fungus spores for several years after the fall of the dead branch. Attention has already been called by the writer to the manner in which different trees heal the wounds caused by dead branches.[1]

There are resin channels scattered through the summer wood. Their number varies considerably in the individual tree. In some trees there are but one or two in a given ring, while six or eight years later there may be two or three dozen.

WHITE SPRUCE.

The White Spruce, *Picea canadensis* (Mill.) B. S. P. (*P. alba* Link), a very much more stately tree than the Red Spruce, grows to a height of 150 feet (about 46 meters), with a trunk 3 to 4 feet (0.9 to 1.2 meters) in diameter. In the Northeastern States it is found in abundance, especially along the coast, and on some of the islands it is the only tree. It is widely distributed to the north and northwest, extending into Alaska. In the New England States it is not as abundant as the Red Spruce and is not used for lumber purposes to the same extent as its near relative.

> In the eastern provinces of Canada, where it is probably the only Spruce cut in large quantities, it is used in construction and for the interior finish of buildings and for paper pulp. * * * White Spruce lumber is also occasionally manufactured in Dakota and Montana, etc.[2] * * *

The wood of the White Spruce is straw yellow, very light, and not strong. Resin passages occur now and then in the very narrow band of summer cells. As an ornamental tree it is more extensively used than the Red Spruce.

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[1] Von Schrenk, H., Two Diseases of Red Cedar. Bul. No. 21, U. S. Dept. Agr., Div. Veg. Phys. and Path.

[2] Sargent, C. S. Silva of North America. **12**:37. 1898.

BALSAM FIR.

The Balsam Fir,[1] *Abies balsamea* (L.) Miller, is a tree common all over New England, springing up wherever the White Pine or Spruce are cut away. It produces great quantities of seed, which germinate readily the succeeding year. The trees are usually smaller than the Spruces, growing to be 50 feet (15 meters) in height and 6 inches to 1 foot (15 to 30 cm.) in diameter. Its wood is used for a cheap grade of lumber, for it is very light and does not have any resisting power. In central Maine it is often cut with the Spruce and sent to the pulp mills. The trees are very subject to the attacks of insects and fungi. The large black ants[2] annually destroy hundreds of trees.

HEMLOCK.

The Hemlock, *Tsuga canadensis* (L.) Carrière, is a stately tree, usually 60 feet (18 meters) in height, having a trunk 2 to 4 feet (0.6 to 1.2 meters) in diameter. It is an important element of the northern forest, and has long been valued for its bark, which is extensively used in the tanning of leather. As an ornamental tree it has few equals among our native trees.

In stately grace it has no rival among the inhabitants of the gardens of the northern United States, when, with its long lower branches sweeping the lawn, it rises into a great pyramid, dark and somber in winter and light in early summer, with the tender yellow tones of its drooping branchlets and vernal foliage.[3]

It is one of the most valuable trees of the Eastern forests. It is estimated that in the year 1887, 1,200,000 tons of bark of this tree were harvested, and although a large part of the timber of the trees cut and stripped of their bark is allowed to rot on the ground it is believed that the average annual value of the material of all kinds obtained from this hemlock is not less than $30,000,000.

The tree is one which grows very slowly. The seedlings are very sensitive to exposure and do not recover readily when injured. The wood is very coarse and brittle and is worked with difficulty. It is, however, used considerably in various localities for a cheap grade of lumber, and at times, when other wood is not to be had, for railway ties, fence posts, and railing, but its resisting powers to weathering influences are very slight.

ARBOR VITÆ.

The Arbor Vitæ, *Thuja occidentalis*, L.,[4] is a tree found throughout the northern parts of New England, particularly in wet, boggy lands, where it forms dense forests, the individual members of which grow

[1] Sargent, C. S. Silva of North America. **12**:107, 108. 1898.

[2] Hopkins, A. D. Preliminary Report on the Insect Enemies of the Forests of the Northwest. Bul. No. 21, U. S. Dept. Agr., Div. Entomology. 1899.

[3] Sargent, loc. cit. 66.

[4] Sargent, C. S. Silva of North America. **10**:126. 1896.

to be 50 feet (15 meters) in height, with trunks 6 inches to 1 foot (15 to 30 cm.) in diameter. The wood is very durable and is on that account prized for fence posts and railway ties, for foundation walls, and for making shingles. The wood itself is rather coarse, yellow brown, and is free from resin ducts. The trees are grown as ornamental trees, particularly in the form of hedges.

WHITE PINE.

The White Pine, *Pinus strobus* L., once so large a factor in the lumber industry of the New England States, is now comparatively rare as mature timber. It is subject to a number of diseases which will be treated of in a special paper. It is left out of consideration on that account in the present report.

TAMARACK.

The Larch, or Tamarack, *Larix laricina* (Du Roi) Koch (*L. americana* Michaux),[1] is a tall, stately forest tree which is found growing with the White Pine and Spruce and in some sections forms extensive forests, especially in low swampy lands. It grows throughout the Northern States, ranging from Maine westward to the western slopes of the Rocky Mountains, and southward to northern Pennsylvania, Indiana, and Illinois, and to central Minnesota. As an ornamental tree it is highly prized because of its graceful habit and thrifty growth. The wood of the Tamarack is extensively used in shipbuilding, for railway ties, and telegraph poles. It is very durable and hard. Compared with the White Oak, it has a crushing strength of 1.38. Dudley[2] says of it:

> The quality of the wood of this tree is such that it deserves to be widely known and more extensively used for ties than it has been. * * * The wood is easily treated with antiseptics to prevent decay, especially with sulphate or acetate of iron, and ties so treated have lasted over thirty years under heavy traffic.

POLYPORUS SCHWEINITZII Fr.

Polyporus schweinitzii Fr., Syst. **1**:351.
Polyporus schweinitzii Fr., Epic. 433.
Boletus sistotremoides Alb. and Schw., 243.

[Figured in Fries's Icon. Hym. No. 179.]

OCCURRENCE.

This fungus is one which is very common throughout the Northern forests on the Spruce and Fir, and, as Dr. Farlow remarks,[3] appears to be very much more prevalent in this country than in Europe.[4] It certainly stands near the top of the list in point of destructiveness.

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[1] Sargent, C. S. Silva of North America. **12**:7. 1898.
[2] Dudley, P. H. Bul. No. 1, Division of Forestry. Appendix I. 51.
[3] Sargent, C. S. Silva of North America. **11**:11. 1897.
[4] Hartig (Lehrbuch der Pflanzenkrankheiten. 177. 1900) says it occurs only on Pines.

It attacks young trees as well as older ones, entering the tree through the root system and growing up into the trunk for sometimes 40 and 50 feet (12 to 15 meters) from the ground. The mycelium makes the wood of the Spruce very brittle. Diseased wood is of a yellowish color; it has a cheesy consistency so that it can be cut across the grain with a knife quite readily and without much resistance. When dry, it is readily powdered. The brilliantly colored fruiting bodies are to be found in July and August growing about the base of the affected trees, more rarely on the trunks. (See text fig. 1; also Pl. I, fig 1.) It was found more frequently in places where the air was laden with moisture—for instance, along the coast and near lakes. On many of the islands which lie off the Maine coast the fungus was found to be very plentiful, even to a distance of 5 miles (8 kilometers) from the mainland, showing that the spores must be carried for a considerable distance. One small island had some 12 trees on it, all White Spruces, of which 7 had old fruiting organs of this fungus growing about the bases of the trunks.

STRUCTURE OF DISEASED WOOD.

The wood of the Red Spruce or the Fir when first invaded by the mycelium turns yellow, and after a time cracks here and there as if dried rapidly. A cross section of the trunk of a young Fir, made about 6 feet (about 2 meters) above the ground, is shown in Pl. II. The large crack at the side was made in chopping down the tree; the other cracks in the heartwood show plainly how the wood has shrunken. The structural changes which take place are as follows: Soon after the mycelium enters the wood of the Spruce the color changes and the wood becomes more or less brittle. This is due to the fact that at various points in the summer wood cracks appear in the walls of the tracheids and extend in the spiral direction around each tracheid. The break deepens gradually until it extends entirely through the secondary lamella up to the primary lamella. The latter remains unbroken. The spiral breaks increase in number and at last the tracheid has the appearance shown in Pl. IX, fig. 1. There appear to be two series of cracks, one extending upward from left to right, the other from right to left. This appearance is due to the fact, as Hartig has shown, that one sees the breaks in the walls of two tracheids at the same time. Hartig mentions that these cracks all extend in a spiral direction, none parallel to the walls. This is certainly a striking fact, and seems to distinguish wood attacked by this fungus from that injured by many others. It will be shown that some other fungi, *Polyporus sulfureus* and a form of *Polyporus destructor* possibly, attack the wood of the Spruce and the Yellow Pine, respectively, in a similar way.

The spring wood has few cracks. These are mainly in the pits, where four radiating cracks appear in the secondary lamella.

Wherever a hypha has passed through a wall is to be found the peculiar double spiral crack. (Pl. IX, fig. 1.)

The diseased wood of the Balsam Fir differs little from similarly affected Spruce wood. The summer tracheids as a rule are not so wide as those of the Spruce, hence the spiral cracks are not as evident as in that tree. They appear to extend more or less parallel with the walls. They are likewise present in greater numbers, so that there is very little left of the wall.

Wood which is in the last stages of decay is exceedingly brittle. It does not partake of the character of brown charcoal as much as does Pine wood similarly diseased, but is much firmer. It absorbs water very rapidly, and when boiled in water for a few minutes becomes soft and putty like and can be kneaded like bread dough. When dry it can not be cut with a knife without crumbling, but when soaked in water it can be readily cut into the thinnest sections. These have no elasticity, however. The walls of the wood cells are very thin and swell to several times their size on addition of dilute potash. Here and there are found masses of resin, more frequently in the Balsam Fir than in the Spruce. As the wood grows older the action of the mycelium seems to stop. The wood changes no further except that it cracks more or less. It appears to be very resistant to change brought about by weathering.

FRUITING ORGAN.

The first fruiting bodies observed began to appear toward the beginning of July. Small rounded masses grew out from the bark and very soon became flattened horizontally. The specimen shown in the photograph (fig. 1) was watched closely and measured daily from the time of its first appearance until it had reached its full size. By means of wires stuck at the edge of the growing shelves, it was easy to measure accurately the daily increase in diameter. The hyphæ rapidly grew around the wire so that it became embedded in the mass of the sporophore. One of the wires is visible at the right side of the middle shelf of fig. 1. The measurements show that for the first two weeks the larger shelves grew about one-fifth of an inch (one-half centimeter) a day in all directions; on warm days, however, the increase was more than that and on other days not so much. The youngest portion of the sporophore was yellow-brown, which in three or four days deepened to a red brown. The unequal development of the mass caused concentric rings to appear on the top of the pileus, showing by the low ridges and shallow furrows, respectively, where any particularly rapid growth had set in and where it had stopped. On August 15 the growth in width suddenly stopped. When full grown, the largest of the three shelves was 16 inches (40^{cm}) across at the widest point and 8 to 14 inches (20 to 35^{cm}) from front to back.

The sporophores grow either on the roots of an affected tree or on the trunk, the former being the usual position. When growing on the ground the pileus is supported on a very short stalk; it is sessile when growing from the trunk. There are usually several shelves which are grown together at the center in the ground form, or grown one above the other in the trunk form (see text figure 1 and Pl. I, fig. 1). The whole body varies greatly in size. The smallest specimens collected during the past summer were 4 inches (10^{cm}) in diameter; the largest about 14 inches (35^{cm}). The hymenial layer begins to form some three days after the body of the pileus is com-

FIG. 1.—*Polyporus schweinitzii* Fr. growing on a fallen Fir.

plete, so that there is always a wide band of sterile hyphæ on the under side of the pileus during the period that the pileus is growing in width. When this growth stops, the tubes gradually form close up to the edge. The hymenium when fresh is rose colored; when touched or bruised it turns dark red very quickly. The bright colors of the young pileus gradually give way to more subdued ones as the fungus grows older. A few days after growth has come to a standstill, the spores ripen and begin to be discharged. They come off in clouds plainly visible to the naked eye. Slips of glass placed under the pileus and left overnight had so thick a layer of spores deposited

on them that it was impossible to perceive anything through the glass. Attempts were made to grow the spores in the woods on bread cultures. These all failed, however, because of constant interference on the part of inquisitive squirrels.

The spores came off at intervals as if they were being discharged by some force acting within the tubes. Pieces of the pileus were accordingly turned over in a jar so that the tubes of the hymenium pointed up. Glass slips were supported over the tubes overnight, and on the following morning a few spores were found on them, but the number was so small when compared with the large number discharged from a similar piece laid with the pores pointing down, that it did not seem probable that there was any very active discharge going on. The spores were borne far away from the spot where they fell. Owing to their exceedingly small weight, every disturbance in the air carried them off. It was surprising to see how slight a disturbance sufficed. The flame of a candle held near the sporophore remained perfectly motionless while clouds of spores were swaying to and fro under the hymenial layers. The spores were sown in aqueous decoctions of humus, but did not germinate. The facilities for doing more careful work were not at hand in the woods, so experiments on the manner of germination had to be left for a future time.

At the time of ripening of the spores it was noticed that hundreds of drops of a yellowish liquid were hanging from the hymenial surfaces every morning when the fungus in question was visited. Some of these drops were carefully collected and were examined. In them floated a number of spores and flocculent yellowish brown masses, which stained yellow with nitric acid. These were present for several days. Thereafter the liquid was almost clear except for numberless spores which were in every drop. For three weeks the drops were collected with a pipette during the day, and during the night a plate, carefully protected against dew and rain, was placed under the fungus. In this way about three-fifths of a pint (300^{cc}) of liquid were collected. This was poured into an open dish and put in a cool place, where the water was allowed to evaporate. A thick brown sirup was left after some weeks, which had the odor of very impure molasses. The sirup was transferred to a vial, which was corked and placed in a warm place. In a few days delicate needle-shaped crystals shot out, which upon examination proved to be melezitose and mycose, sugars sometimes found in fungi.[1]

At the same time that this secretion appeared on the hymenium, or rather shortly afterwards, a number of small beetles began to devour the hymenium with great avidity. So active were they that within

[1]The writer is indebted to Dr. O. Loew for the determination of these sugars.

three weeks of their appearance the hymenium was entirely destroyed, and of course with it whatever spores had remained. It is suggested that the secretion of this sugar and the destruction of the hymenium by these beetles may have some meaning in connection with the dispersal of the spores. It is a point worthy of further observations by local observers in future years. The rapid destruction of the hymenium is very marked. It is exceedingly difficult to get perfect specimens of the sporophores after the end of August. The upper surface, which is usually moist, becomes covered with a fine layer of fallen spruce needles, and before long a covering of mosses hides the brown sporophore completely. It is no unusual occurrence to find these old moss-covered sporophores several years after their formation, at the base of some old Spruce.

The basidia and spores have nothing about them which is very distinctive. Numerous peculiar hairs project from the hymenium, which are surrounded with a film or drop of clear liquid in which numerous spores are caught. When viewed by reflected light these glisten like dewdrops within the pores. The latter are exceedingly irregular, so irregular in fact that one can hardly call them pores. They partake more of the nature of pockets, which are divided by many much convoluted walls into various chambers. The pores extend almost to the margin of the pileus and are usually about one-eighth of an inch (3^{mm}) deep.

EFFECT OF FUNGUS ON THE TREE.

The fungus seems to spread through the ground, attacking the tree first at its root system, and growing thence up into the trunk. Wherever one tree is affected, others similarly diseased will usually be found close by. Infection may take place through the root on one side of a tree. The heartwood of that root will be destroyed and then the wood of the portion of the trunk nearest that root becomes affected. Many trees were cut down where but one-half of the trunk had been rotted by the fungus, and oftentimes only a small spot was visible where the fungus had just begun to grow. The tree continues to stand until either the roots or the trunk become weakened to such an extent that they can no longer hold the tree erect, and then the first wind storm overturns it. Fig. 1 shows a large Fir, the root system of which was almost entirely destroyed. In its fall the lower part of the trunk split, revealing decayed wood to a distance of 12 feet (about 3⅝ meters). The tree was probably blown over in the spring of 1899, and in the following July the sporophores formed on the trunk. A large tree thus diseased is a constant source of danger to all others about it. Not only may the disease be communicated to them, but in its fall such a tree breaks down many a small tree, not to speak of the large numbers of very small second growth which it destroys. The sporophores form

on fallen trees for several years in succession, possibly omitting a year now and then. As a rule but one set of sporophores is found on one tree. As has already been said, young trees are subject to the attacks of this fungus as well as older ones, although the latter are probably more so, because the points of infection are so much more numerous. Nothing is known as yet of the manner in which the fungus enters the tree, nor of the rate at which it grows within a tree after having obtained a foothold.

TREES ATTACKED.

Polyporus schweinitzii was found growing on the roots of the White and Red Spruces, Balsam Fir, and Arbor Vitæ. It is likewise common on the White Pine (*Pinus strobus*).

METHODS OF COMBATING THIS FUNGUS.

Because of its destructiveness *Polyporus schweinitzii* is perhaps the most to be feared, where living trees are concerned. As it spreads through the soil it is difficult to detect, and still more difficult to combat. In the European forests a deep trench is dug around an infected tree or group of trees; this trench prevents the spread of the mycelium through the ground to neighboring trees. Such a method can not be recommended for American forest-tree conditions, at least not for the present. If a group of infected trees is met with in the forest while lumbering it may prove advantageous to cut all trees in the vicinity of the diseased ones. Some of these may produce a hollow sound when hit near the base, an indication that the decay has started. It may not have gone up into the tree very far as yet, so that one or more logs can be obtained from the top. It will not be profitable to hunt out diseased trees as is done in European forests. There is as yet no evidence that the fungus can infect a tree above ground, consequently it need not be feared in burned-over regions, or such as have been attacked by bark beetles.

POLYPORUS PINICOLA (Swartz) Fr.

OCCURRENCE.

This fungus occurs widely distributed over the world, growing on conifers and occasionally on Birches and other deciduous trees. In the New England forests it is one of the most frequent fungi found on living or more often on dead trees of Spruce, Pine, Fir, and Hemlock. From three to ten of its bright colored sporophores may grow on a single log for several, varying from three to five, years. At the end of that time the mycelium has used up the available food supply in the log and dies.

The sporophores grow on living trees, but these always appear weakened or sickly. No vigorous, healthy trees were found on which this fungus flourished. It is essentially a wound parasite, entering

the trunks and branches above ground. Old knot holes or branch wounds, wounds produced by fire, or wounds made by animals, are favorable spots for the entrance of the spores. Wherever a tree dies from any cause this fungus is sure to attack it before long. In the sections where the bark beetles had been active some years ago there were many trees the wood of which had been destroyed by this Polyporus.

The large holes made by woodpeckers offer excellent opportunities for the entrance of spores. As the woodpeckers are very active in exterminating insects inhabiting the bark (presumably the bark beetles among others), we have here a case of their allowing one enemy to enter while destroying another. In old windfalls the dead trees were covered with sporophores, some of them many years old, showing that these trees had become infected very soon after the trees had been blown over. This fact is of importance, as it suggests that these trees could be saved by the lumberman if carried to the mills shortly after their downfall. This will be referred to again. Plate IV is from a photograph of a portion of a Spruce trunk. The small white spots in the bark are holes of a borer filled with the mycelium of the fungus.

STRUCTURE OF DISEASED WOOD.

Wood of the Spruce in which the mycelium of this Polyporus has been growing for some time deserves the description "entirely rotted" par excellence. The wood has been changed to a brittle red-brown mass, which has cracked in many directions. The individual pieces are barely held together by countless sheets of mycelium which have filled the spaces resulting from the cracking of the wood and form an intricate network of larger and smaller sheets. In Pl. IV a portion of a log in the last stages of decay is shown. At one side a sporophore one year old and another just beginning are visible. The sapwood has numerous tunnels of a borer filled with remnants of the borings. Such wood has lost all strength, and falls to pieces at the slightest touch. If the mycelium attacks a standing tree the decay goes on within it until the trunk becomes so weak that an ordinary wind blows it over. The shrinkage which takes place in the wood as it is being metamorphosed is very considerable, as is evidenced by the large number of wide cracks which fill it, passing both across the annual rings and parallel to them.

The changes which result in the wood may be described as follows: In a tree just attacked the wood about the point of entrance of the fungus turns darker and finally becomes a decided red-brown. Before long small whitish areas appear here and there scattered irregularly through the wood. Some of these are mere lines, while others form white patches circular in shape, surrounding small areas of wood about the size of a pinhead, which are red-brown (Pl. III). Others again have

the shape of broad, irregular bands, which extend across the rings of growth. The points at which these white areas appear and the direction which they take do not seem to be controlled by any particular factor, for they are exceedingly irregular. The areas are shown in Pl. III, which represents a radial view of a spruce log in the early stages of attack by the mycelium. The very fine white lines which are visible near the center of the log, extending across the annual rings, are of a different character from the white areas spoken of. It will be noted that in the white areas the parallel lines which indicate the summer wood are very distinct. A microscopic examination of a white area shows that at this point the cells of the wood are completely filled with fine hyphæ, which form a dense mass within that area. Mixed in with the mycelium are the granules of an amorphous substance, readily soluble in alcohol, which is evidently resin. This, together with the mycelium, gives the white appearance to the spots. As the summer tracheids have a very small lumen, they have comparatively little mycelium, which accounts for their being visible as lines extending through the areas. The size of an area is thus dependent upon the distance to which the mycelium has grown, and probably varies from time to time. It is suggested that the smaller areas are also the ones most recently invaded. At this stage of the decomposition the mass of the wood is already very brittle. Here and there cracks have appeared in the walls of the wood cells wherever a hypha has passed through them. Some tracheids appear like sieves because of the numerous holes. The changes subsequent to this stage of decomposition consist essentially in a carbonizing of the wood and the formation of the sheets of mycelium. The former change is one probably induced by some ferment, the nature of which it is the intention to discuss more fully in another report. The cells of the wood gradually show more and more cracks and fissures, and the diameter of the walls decreases about half. The main shrinkage takes place in the secondary lamellæ. The fissures which appear in the spring wood usually emanate from the holes formed by hyphæ. The outline of these holes is irregular, but approaches a circle in form. In the secondary wall a fissure is soon formed which extends diagonally from left to right across the cell. Viewed from the top there are apparently two fissures, but these can readily be shown to belong to the secondary lamellæ of adjoining cells. The fissures never extend into the primary lamellæ. Various stages of such fissures are shown at Pl. X, fig. 4. In the bordered pits at first two and later four fissures are visible in the secondary ring, which, as Hartig has surmised,[1] are probably brought about by drying. Here and there (Pl. X, fig. 4, c) a hypha has passed directly through a bordered pit and in its passage has

[1] Hartig, Robert. Zersetzungserscheinungen des Holzes, etc.

dissolved more or less of the membranes. In the summer tracheids the number of fissures in the walls is very large. They all extend diagonally across the tracheids as in the spring cells, and wherever a hole occurs there two fissures seem to cross. The smaller fissures have no counterpart in the secondary lamellæ of neighboring cells as a rule, showing the complete independence of the two halves of the cell wall. The margins of the fissures are ragged, and the fissures themselves are very irregular in shape, and look as if they had been formed suddenly. The wood substance itself has been changed completely. With phloroglucin and hydrochloric acid it stains red, and when the wood, finely powdered, is extracted with absolute alcohol quantities of hadromal are obtained. No reaction for cellulose can be obtained, and it seems as if the latter has been completely destroyed. An aqueous solution yields several compounds—an amorphous substance, possibly a humus compound; a faint trace of some sugar, as shown by the phenylhydrazine test; and small quantities of citric and succinic acids. These are doubtless all decomposition products. There is also some compound present which reduces Fehling's solution vigorously. After the walls of the tracheids are filled with holes and fissures they have reached the last stage of decomposition. A touch will then cause them to fall into many pieces. When boiled in water, the walls swell somewhat, and a pasty mass results when squeezed. With dilute KOH the walls swell to three times their size, and portions of them dissolve completely.

The formation of the sheets of mycelium seems to take place in one of two ways. In one case the hyphæ in the white areas mentioned above exert a solvent action on the walls. This first becomes evident in the cells of the medullary rays. Their walls disappear completely, and the spaces are rapidly filled by the growing mycelium. The walls of the wood cells adjoining the medullary rays are attacked, possibly at the same time. The secondary lamellæ shrink and finally disappear altogether, leaving a fine framework of the primary lamella. This framework is usually broken in hundreds of places, and as a result only pieces of the walls remain embedded in a web of hyphæ. The bordered pits are destroyed from within outward, the torus resisting longest (Pl. X, fig. 5). The latter is often freed and can be seen lying free in the cell. The triangular areas (as seen in cross section) of the primary lamella, formed where several cells join, are the last to disappear. A hole is thus formed which is completely filled with mycelium. The latter spreads from this point in several directions. The writer is of the opinion that very little actual solution of the wood takes place, resulting in the formation of holes or cavities. Here and there it doubtless does occur, but rather as the exception, and possibly in the early stages of the development of the mycelium. It seems very much more probable that the second mode is the usual one. As

the mycelium spreads through the wood it brings about the chemical changes spoken of, extracting substances from the walls. This reduces the volume of the wood and causes the fissures in the cells. But before long the shrinkage becomes so great that larger masses of the wood suddenly break away from each other at many points throughout the wood. Many small fissures are thus formed, which extend in every direction, both across the rings and within them in a tangential direction. The fissures are very irregular. Sometimes they extend for a short distance within one ring, then cross over into another, and so on. They appear both in the spring and summer wood, and not infrequently start in one ring and extend radially through the summer wood of that ring into the spring wood of the next. Often the breaks follow the lines of the medullary rays, but just as often they do not (Pl. X, fig. 1). The process is evidently one of drying, for the same result is seen when wood dries, resulting in the formation of fissures, the so-called "checking" of wood. If the fissures are near points where mycelium of the fungus flourishes, the latter grows into the spaces and fills them completely. Several fissures may join, forming an irregular longer one. In Pl. X, fig. 1, a sketch is shown of the cross section of several annual rings, showing how and where the breaks have formed. As the wood dries more and more the fissures widen and the mycelium keeps step with them. In small fissures it is very evident that the fissure has formed as a break and not by the solvent action of the mycelium. Fig. 2 shows such a fissure filled with mycelium. (The same figure is shown at *c*, Pl. X, fig. 1.) A glance at the rows of wood cells will show how they have been forced apart, breaking one row. The rows are inclined toward one another, as one would expect them to be. The figure also shows a medullary ray at the right, the walls of which have disappeared. In the cells surrounding the break the mycelium flourishes, and here and there some of the walls are destroyed, making a small hole.

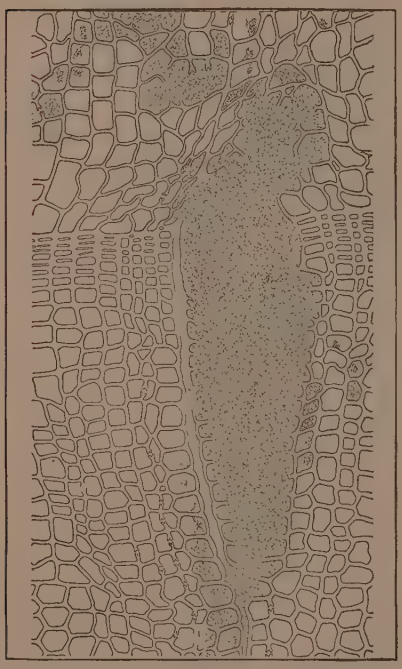


FIG. 2.—Cross section of Spruce wood showing masses of mycelium of *Polyporus pinicola* (Swartz) Fr.

In the last stages of decay the fissures are very numerous, each filled with a solid felt of white mycelium. The felts extending in radial lines join those extending in tangential lines here and there, and they hold in place the wood which would otherwise have fallen to pieces long before. In a live tree the heartwood is attacked first, and gradually the decay spreads to the sapwood. In the latter the browning of the wood is more marked, owing to its lighter color. Nothing positive can be stated at present as to the rapidity with which the decay brought about by this fungus proceeds. It appears to be very rapid, for trees blown down some two years before were found in an advanced stage of decomposition, with sporophores forming on their trunks at various places.

FRUITING ORGAN.

The sporophores of this fungus are very large and conspicuous, and are formed on logs during spring and summer, often many together on the same log. The form of the pileus is exceedingly variable (Pl. V). It is entirely resupinate when growing on the lower side of an overturned log (Pl. IX, fig. 6). In such a case there is no upper surface for several years. After three or four years the edge extends out beyond the curved surface of the log, and a narrow surface is exposed. Usually the pileus forms a distinct bracket on the side of a standing trunk or log. This bracket is sometimes hoof-shaped, then again very much extended. In size it varies from an inch to a foot (2.5 to 30^{cm}) in width, or even more in extreme cases. The average specimen is 4 to 6 inches (10 to 15^{cm}) wide. The upper surface of the bracket slopes toward the margin, and is divided into a number of regular divisions or lobes, which correspond evidently to periods of growth (Pl. V). The lobes are smooth and dark red-brown when old. The youngest lobe is bright red, shading into a pale yellow at the very edge of the pileus. In many specimens the upper surface is almost black, and some of the lobes shine as if varnished. The number of lobes varies with the age of the specimen; one of the oldest found had fourteen. It has not been determined whether these lobes represent annual increments of growth, so it is not possible to say how old any of these large sporophores may be. The mass of the pileus is extremely hard and woody, and shows division into a number of zones (Pl. IX, figs. 5, 6, 7), which are always greater in number than the lobes showing at the top. The hymenium is a pale yellow, very smooth, and assumes a watery appearance when bruised. It is very rarely perfect, as many insects are constantly at work eating away the tissue. The outer edge of the lower surface of the pileus is raised, forming a distinct ridge. At the inner edge of this ridge the formation of the tubes of the hymenium begins. This ridge is continuous around the whole lower surface and forms a character which is very constant. In young individuals it is wider than

in older ones. It is composed of loosely interwoven hyphæ, which form a continuation of the main hyphal strands which compose the body of the pileus. The hyphæ of the latter start from a central point on the bark and radiate out in several directions (Pl. IX, fig. 7), forming a mesh which at first is very loose. The hyphæ are almost colorless and have a decided lumen. As they grow older their walls become brown and very thick, so that the lumen is reduced to a very small one. The peripheral growth of the hyphæ takes place in such a way as to form well-defined layers. For several years these layers are added one outside of the other. The lowermost portion of each layer is usually less dense than the outer portion, and after the hyphæ turn brown large masses of crystals of calcium oxalate are deposited in the meshes of the outer portion. The alternation of layers of less density with those of greater density makes a differentiation of layers possible. The layers vary considerably in width (Pl. IX, figs. 5–7), and it is suggested that this is probably due to varying conditions; probably the amount of food supplied and the amount of available moisture exert a marked influence. The pileus grows in width and length by the direct elongation of the hyphæ of the last layer. After several years' growth the hyphæ on the under side of the developing shelf grow down in a vertical direction and give rise to the pores.

The pores are very long and are continuous from year to year. After a time they become plugged at the bottom by hyphæ which grow into them from all sides. Different sporophores differ in this respect. With some the pores are open through eight or ten of the recent layers; in others the growth of hyphæ is so vigorous that the pores are closed almost as rapidly as they are formed. The hymenium arises on the surfaces of the pores from hyphæ of the trama which turn at right angles to the general direction of the tramal hyphæ. The latter have very thick walls (Pl. IX, fig. 12) and extend longitudinally, forming a very loose network. The tips of those hyphæ which form the hymenial layer are thin walled. The hymenial layer itself is composed of hyphæ of almost equal width. The layer is a very narrow one. Cystidia are practically absent. The basidia barely rise above the general surface and do not differ materially in form from the paraphyses. The four spores are colorless. Amid the tramal and hymenial hyphæ accumulations of calcium oxalate crystals, colored red-brown, occur in great numbers, likewise large quantities of an oil readily soluble in ether and becoming solid at about 59° F. (15° C.). The growth of the hymenial layer is very irregular. At one and the same time pores may be forming on one side, while at the opposite side the old pores are completely plugged. The hymenium renews itself at frequent intervals. The vitality of its hyphæ is very great, for it is not at all rare that insects eat away a considerable portion of the lower side of the pileus. These parts die and turn brown.

The remaining portions then form separate centers of growth, which gradually spread over the dead portion and unite, after several years perhaps, completely covering the dead part. A view of such a pileus is shown on Pl. IX, fig. 4; several areas have already joined, forming a larger one, and a number of small centers are evident.

The spores begin to be discharged in July. Growth of the lower side of the pileus takes place at the same time. Black cloths were pinned to the under side in June and by the end of August large portions of them were found completely overgrown with hyphæ, and pores were beginning to form on the under side of the cloth. While the growing season lasts drops of a glistening yellow liquid are constantly being discharged from the hymenium. It is of interest to note here that the secretion of these drops was noticed by Fries in a description of this fungus.[1] Several cubic centimeters of these were collected and were found to hold in solution melezitose, the same sugar discharged from the sporophores of *Polyporus schweinitzii*. As insects, particularly small boring beetles, eat the hymenium with great avidity, it is possible that the sugar may serve to attract these insects to the sporophores, causing them to carry the spores to uninfected trees.

TRAMETES PINI (Brot.) Fr. forma ABIETIS Karst.

Polyporus piceinus Peck.
Polyporus abietis Karsten.

OCCURRENCE.

This fungus is very common in the forests of the New England States, and occurs northward into Canada and Newfoundland. The writer found it common on the Spruces and Firs in the Adirondack forests. It grows on nearly all the conifers and has been found by the writer on the White Pine (*Pinus strobus*), the Red Spruce (*Picea rubens*), the White Spruce (*Picea canadensis*), the Hemlock (*Tsuga canadensis*), the Larch, or Tamarack (*Larix laricina*), and the Fir (*Abies balsamea*). It attacks living trees after they have reached such a size that they form heartwood, and honeycombs the wood in such a way that it appears filled with small holes, many of which are coated with a shining white lining. The changes which are brought about in the wood are different somewhat for the different kinds of trees and will be described separately. Of the six trees the Tamarack seems to be the most readily attacked. A greater per cent of the older trees of this species were found affected than of the other five. The Spruces came next, and the Balsam Fir last.

The fungus enters the trees through the stubs of broken branches

[1] Fries, Elias. Epicrisis Syst. Myc. 468. 1836–1838.

and through wounds. The mycelium flourishes in both heartwood and sapwood of the Spruces, the Fir, and Tamarack, and is confined to the heartwood in the Pine. It grows up and down the trunk from the point of infection, reaching into the root system and extending into the larger branches of the top. Affected trees may remain standing in the forest for many years until some more violent storm breaks the trunk at a weak point. The wood of the trunk is never destroyed completely, as in the case of the two fungi described above. In the most advanced stages of decay some fibers of unchanged wood are to be found. The extent of their presence varies with the tree.

DESTRUCTION OF SPRUCE WOOD.

The first effect noticed when the mycelium grows in the wood of either of the Spruces is a change in color from the light straw yellow of the normal wood to a light purplish gray closely approaching the color indicated on the Milton Bradley Color Scale as Neutral Gray No. 1. Very soon this gray deepens to a red brown, the gray remaining as an outer ring surrounding the portions of red-brown wood. Small black lines appear scattered here and there through the red wood. These lines are present throughout an annual ring and extend longitudinally in the direction of the wood fibers for a distance of $\frac{1}{50}$ to $\frac{1}{25}$ of an inch (0.5 to 1 millimeter). Gradually the black lines disappear and here and there small white areas appear (Pl. VI, fig. 1). The central portion of each area is absorbed and small holes are formed, which have white linings of loose fibers. The holes are at some distance from one another and are generally arranged in rows corresponding to the annual rings. Where the latter are very wide there may be a row of holes in each ring. The holes generally have their centers within the summer wood of the annual ring, but as they increase in size portions of the spring wood of that particular ring, as well as the spring wood of the following ring, are included. The holes have a more or less spherical shape, which soon changes to a more or less elongated form, the greatest diameter extending radially. Pl. X, fig. 2, shows a cross section of a piece of wood at an early stage of the destruction. Some of the holes at this period are filled with a mass of white fibers, so that there is practically no hole. The outlines shown in fig. 2 of Pl. X represent the outer limiting line of the white fibers, and the dotted lines (where present) indicate where the actual cavity begins. As the growth of the mycelium progresses, the holes increase in size and their walls approach one another until only a narrow lamella is left (Pl. X, fig. 3).

A large number of holes appear between the original ones, and in the final stages there is practically no wood left except the narrow walls separating two holes (Pl. X, fig. 3, and Pl. VI, fig. 2). Adjoining cavities rarely, if ever, unite to form a larger one in a lateral direction. They often unite at their upper and lower ends, forming

a longer hole. The holes are never sharply defined, for there is always more or less of a white mass of metamorphosed fibers which remain in position next to the unchanged wood, and in many cases the whole area is thus occupied, and one can recognize the change only by the white color. In older holes this lining is often replaced by felts of brown mycelium (Pl. X, fig. 3) which partially or completely fill the cavity. The lamellæ of wood between the holes ultimately become of an almost uniform thickness (Pl. X, fig. 3), and on cross section show one or more black lines which extend completely around each cavity at an equal distance from the walls of two adjoining cavities. These black lines begin to appear at a stage intermediate between that shown in fig. 2 and fig. 3 of Pl. X. They are of variable width and grow darker and more marked as the decomposition advances. A longitudinal section shows that they extend around the holes in a vertical direction also; in other words, a thin layer of dark-brown matter surrounds the individual cavities. A closer examination shows that the brown lines are due to masses of dark-brown hyphæ which fill each separate wood cell so completely as to plug it entirely. The hyphæ are closely matted together and are incrusted with a brown substance which dissolves in part in dilute KOH and entirely in warm nitric acid. These hyphal plugs occur in every tracheid surrounding a hole and fill it for a shorter or longer distance. The plugs of adjacent cells may be continuous, or may follow one another much as a series of steps. This is shown in Pl. IX, figs. 10 and 13. The latter represents a radial view of a number of tracheids at one side of a hole. The parts of the tracheids toward the hole (*t*) are completely changed to white cellulose fibers, while the parts on the other side of the plug (*l*) give lignin reaction. The brown hyphæ fill the wood between the holes rather loosely, and it is only when about half way between two cavities that they become matted together so as to form the plugs. The brown incrusting substances occur in or on the cell walls in the immediate neighborhood of the holes, and the manner of occurrence leads one to suspect that they were deposited in liquid form, for they have diffused through the various cells in all directions from the wall of the cavities.

The changes in the cell walls which result when the mycelium attacks them are practically those so fully described by Hartig.[1] There is a gradual extraction of those elements which give the so-called lignin reaction, the hadromal of Czapek. This begins in the tertiary lamella and proceeds outward slowly through the secondary lamella. The primary lamella at this period splits in the middle and is shortly after dissolved, leaving the individual tracheids entirely free from one another, each composed of approximately pure cellulose.

[1] Hartig, Robert. Zersetzungserscheinungen des Holzes, etc. 32.

The parts of the primary lamella which are situated between three or more cells resist longest (Pl. IX, fig. 9, *p*) and can be found free between the white cellulose fibers. The change to cellulose apparently takes place simultaneously over a considerable area. The first evidence of this change is to be seen in the white spots which come after the black lines. The white spots are the points at which the change to cellulose has taken place. The cellulose fibers are absorbed later on, giving rise to the holes already mentioned. Preceding the change from wood fiber to cellulose the wood is full of hyphæ, which become massed in centers here and there and bring about the dissolution of the wood. It is as yet undetermined what causes influence this local initiation of the changes, which is characteristic of several other wood-destroying fungi. The growth in size of the white spots or cavities takes place rapidly. The hyphæ grow out in all directions from the original center, and as they do so the products of decomposition pass outward likewise, passing along the tracheids faster than across them. After a period the advancing hyphal masses of two adjacent holes meet in the narrow lamella of unchanged wood between the two. A quantity of brown substance, representing decomposition products, has by this time accumulated. It fills the tracheids and coats the hyphæ so that these turn very dark, almost black. Warm nitric acid removes these substances entirely, leaving the hyphæ and wood almost colorless. It is the opinion of the writer that this accumulation of the products of decomposition may account for the fact that the destruction of the wood stops at this point, thus preventing the total destruction of the wood substance. That this can not be true in all cases is shown by the fact that many of the cavities join in the direction of the fibers, but in this instance it is probable that diffusion takes place to more remote places. The mass of cellulose within the affected areas consists of free fibers which remain in place for a period and are then gradually dissolved here and there, leaving an actual hole with a lining of white fibers.

In the newly invaded parts of a trunk the mycelium is colorless and fills the tracheids completely. The individual hyphæ are somewhat thick-walled and have numerous short branches which penetrate the cell walls in all directions, leaving the characteristic figure 8 holes described by Hartig and others.

Here and there a second form of decomposition occurs in which there is no reduction to cellulose. The process, as found in the spruce, is essentially the same as described by Hartig. The secondary lamellæ are gradually absorbed, leaving the primary lamella intact. The wood gradually changes into a mass of red-brown fibers which fall apart at the slightest touch.

The destruction of the wood takes place throughout the trunk, including the heart and sapwood, and finally even the bark (see Pl.

VI). A trunk like that from which the log shown in Pl. VI, fig. 2, was taken decays no further, and may stand in the forest for many years. After a tree has once fallen the destruction seems to stop. Two trees under observation for more than a year did not change at all. In both the decomposition had reached, in 1898, the stage shown in fig. 2, Pl. VI, and in September, 1899, no further change could be detected. Further observations in this connection are desirable. This point is perhaps not as important from the standpoint of the forester as the power of the fungus to form fruiting organs after the fall of a tree, and this assuredly takes place with this fungus for several years, as will be mentioned.

DESTRUCTION OF FIR WOOD.

The destruction of the wood of Balsam Fir, *Abies balsamea*, does not differ materially from that of the Spruce. White spots appear in newly attacked wood, which soon grow into larger ones; the black lines surround the individual holes sooner or later and then the decay ceases. On Pl. VII a radial view is shown of a log taken from a Fir which had been blown down during the past summer.

DESTRUCTION OF TAMARACK WOOD.

The process of destruction is very different in the Tamarack. This is probably due to the different nature of the wood of this tree, which seems to be far less resistant than the others. In the Tamarack the decay goes much beyond that described for the Spruce and Fir. In the early stages (Pl. VIII, fig. 1) small white spots appear, which usually occupy the entire width of an annual ring. Two or more of these spots soon join, at first in a longitudinal direction, then laterally also. In that way it happens that very early in the process of destruction long stretches of one or more rings of wood are transformed to cellulose. This is well shown in fig. 1 of Pl. VIII. This brings about the separation of one or more rings from the adjoining ones, forming in that way a series of tangential plates which can readily be separated. In the figure each one of the plates visible at the upper end represents one annual ring. The line of separation between the rings is always at the point where the summer wood stops and the spring wood of the following year begins. As the decay continues, more and more of the sound wood fibers are attacked, leaving loose cellulose fibers. When most of the wood has disappeared, black lines similar to those described for the Spruce appear, but as there are no such centers of decay as in that tree the lines are scattered irregularly. It would seem as if there were few decomposition products formed in the Tamarack, and then only at a very late date. Ultimately the tangential plates become extremely thin; they are then composed of the more resistant summer wood cells of this or that wood ring, which are more or less infiltrated with resin. The whole body of the former wood is

a mass of separate fibers, which can be pulled out individually. This can be seen at the ends of the piece of wood shown in fig. 2 of Pl. VIII.

FRUITING ORGAN.

The fruiting organ of this fungus is exceedingly common on all the affected trees and has been collected in Maine, New Hampshire, Vermont, in the Adirondack forests of New York, and in the forests of Toronto, Quebec, and New Brunswick. It is readily distinguished from allied forms by the light red-brown color of the hymenial surface, the regular small round pores, and characters of the hymenial layer shortly to be described.

The form of the pileus varies exceedingly and is almost a distinct one for every host plant. Hartig, in describing what evidently corresponds to this fungus, ascribes the difference in form of the pileus and position on the trees to the different amounts of resin or turpentine which the wood of the different trees contains. *Trametes pini*, according to him, forms brackets around the stump of dead branches in the Pine, the Spruce, and the Larch, while on the Fir the sporophores may appear at any point on the bark. This is true only to a certain extent for the trees of the Northern woods. *Trametes pini* is a very common fungus on nearly all the pines so far seen, and on these trees it always forms very large brackets, which grow, as Hartig says, from old branches. On the Spruce, the Fir, and the Tamarack this does not hold, for on all three of these trees the sporophores form at the ends of old branch stubs and at scattered points on the bark. The resin content of the Spruce is somewhat higher than that of either Tamarack or Fir, and on that account, possibly, the sporophores are more common at the ends of branches. In Pl. XII a number of the forms as they are found on the White and Red Spruces are shown. The bark of these trees consists of corky scales which are constantly being peeled off by newer ones developing beneath. The mycelium of the fungus, after having penetrated through the sapwood of an affected tree, grows rapidly into the younger parts of the bark and ultimately appears as small cushions under several of the bark scales. These cushions are bright red-brown and have a velvety margin composed of thick-walled hyphæ, which rapidly spread out over the adjoining scales, forming a flat sheet (fig. 4). While the growth in a lateral direction is going on, and when the flat sporophore is scarcely one-sixteenth of an inch (about 1.5^{mm}) in width, some of the central hyphæ elongate, leaving small pockets between them which form the pores of the hymenium. The lateral growth may go on for several years, while at the same time a downward growth of the hyphæ which form the walls of the pores brings about an increase in thickness. It ought to be said that this type of sporophore was found only on the under sides of fallen logs or branches. When the sporophores form on a

living standing tree they take the form of extended sheets on the lower side of the uppermost branches or form as sessile brackets of varied shape around old stubs of branches or again as sessile brackets at scattered points on the side of the main trunk. Fig. 3 shows a sporophore growing on the under side of a branch. In such a case the mycelium grows out through the bark, forming a long velvety cushion oftentimes several feet in length. This cushion rapidly grows laterally, and on its lower surface the pores arise. The growth of such a sporophore may go on for many years. The under side of the branch shown on Pl. XII, fig. 3 was covered for a distance of 10 feet with the brown sporophore. As the latter increases in width it sooner or later develops a free upper surface where the body of the sporophore projects beyond the curved surface of the branch. The cracks appearing in the wood are due to drying. Fig. 6 shows the sporophore as it occurs on the vertical trunk of a living tree. Here a form results which approaches most closely to *Trametes pini* (Brot.) Fr. The mycelium grows out from between the bark scales, forming a small knob or sometimes several beside or above one another. On the lower side the pores soon appear as shallow pits, which are increased in depth by downward growth of the hyphæ forming their walls. The upper surface of the cushions becomes brown and, because of alternate periods of growth and rest, concentric lines arise which are more or less obscured by the hairiness of the surface. In forms of this kind the directive influence of geotropic forces on the position of the pores is very marked. The pores always extend vertically, and on that account when found on a perfectly horizontal surface their openings are almost round. As one passes on into the oblique portion of the lower surface the openings become more irregular and the lower end portions of the tubes are exposed until they appear as hollow grooves. Where for any reason the position of the trunk or branch upon which a sporophore grows is changed, the direction of the pores changes likewise, and instances of this kind are very common.

On old Spruces ends of broken branches are points where the brown sporophores of this fungus may be found almost without exception. Two cases of this kind are shown on Pl. XII, figs. 5 and 7. The Spruce loses many of its branches during windstorms, far more so than the Fir or Tamarack. The butt end of a broken branch keeps on growing after the death of the outer portion, and in that way large knobs are formed which may in time cover the wound entirely. It is an exceedingly slow process, however, and where, as is frequently the case, the branch breaks off at a distance of a foot or more, as shown on Pl. XII, fig. 5, it rarely if ever heals over.[1] Such branches form the places

[1] There is apparently in the Spruces little of that most efficient natural pruning which takes place in the Pines, where a dead branch breaks off very close to the trunk.

where the spores of this fungus find a most suitable place for entrance into the trunk. The spore germinates and the mycelium grows down through the dead heartwood of the branch. From there it spreads through the heartwood of the trunk, growing both up and down. The growth in these directions takes place more rapidly than the lateral growth. When the sapwood is reached, the progress is a slow one, owing to the resinous contents. At about this time the sporophore begins to form. The wood of the callus and the living sapwood of the knob become so thoroughly impregnated with turpentine that the mycelium does not grow in them, but grows out through the dead wood of the branch. At the first point where the hyphæ can reach the air without having to go through the collar of sapwood they emerge. Where the dead branch has broken off close to the callus the hyphæ grow out from the stub and form a cushion on it. More frequently, however, the red-brown cushion is formed at the point where the living callus touches the dead wood (Pl. XII, fig. 5). The cushion is at first very small and looks as if covered with velvet. The hyphæ rapidly grow radially and form a sheet which adjusts itself to the shape of the callus and branch. At the edges this sheet projects from the bark and forms an irregular shelf, the top of which after a time becomes zonate and brown-hairy, as in the more strictly bracket-like forms. On many old Spruces there are deep clefts between the various bark scales, and in them sheets of the sporophores form whose folds fill the crevices completely, forming pores on the outer surface of the newer bark and the inner surface of the old scale. Growth takes place rapidly during the latter part of summer and early fall so far as could be noted. The hyphæ at the edge extend the area of the sheet, while those forming the walls of the pores grow vertically downward. Within the pores many hyphæ grow into the holes, so that after a year or two these are completely plugged at the base. There are at present no means of judging how old one of the sporophores described may grow to be. The oldest one found was about four-fifths of an inch (2^{cm}) in thickness.

Trametes pini forma *abietis* was found but rarely on the Fir. Its sporophores assume on this tree a different habit from those on the Spruces. On vertical surfaces a distinct sessile pileus is formed, resembling a bracket, rather than a hoof, as do those on the Spruce. The mycelium, after having grown throughout the heartwood, grows into the sapwood, where it flourishes much more vigorously than in the Spruce because of the absence of resin. From the sapwood the hyphæ enter the bark and break through it all over the trunk. At the points where they emerge they form small cushions, light red-brown in color, which are at first the size of a pin head, but rapidly increase in size (Pl. XII, fig. 1). When barely $\frac{2}{25}$ of an inch (2 ^{mm}) in width, a differentiation into an upper and lower surface takes place. A band of

very loosely interwoven hyphæ grows out at right angles to the bark. From the lower side of this band some hyphæ split off and grow downward, adhering closely to the surface of the bark. Other hyphæ also turn down, growing faster at several points than at others, thus giving rise to small pits, which form the beginning of the pores. The pits are very variable in size. When they are still scarcely recognizable the hymenial layer begins to form in them, as evinced by the black cystidia which can be seen projecting from the lower surface of the band first mentioned even before any sign of a ridge is evident to indicate where the next pore is to be. Growth in these directions goes on rapidly. The hyphæ of the original band grow on horizontally, forming a rounded edge of loose hyphæ, which give the hairy appearance to the margin. At intervals, where the growth of the sporophore ceases, some of these loose hyphæ stop growing, and when growth is resumed are left, forming a brush-like projection on the upper surface. These hyphæ give the concentric appearance noted above for the Spruce. The hyphæ on the lower side of the band grow downward to form the pores, and those adhering to the bark grow in the same direction, thus increasing the thickness of the pileus in that direction. A large number of small cushions usually start together on the bark, many of which join as their edges approach one another, forming a series of more or less imbricated sporophores (see Pl. XII, fig. 1). On horizontal surfaces the pileated form is lost, and sheets much like those found in the Spruce are formed. The pores in all the specimens on the Fir are more irregular than those found on the Spruce, but in all other important characters they are identical.

On the White Pine the pileus is sessile and occurs at old knot holes.

On the Tamarack both brackets and sheets are formed. The largest bracket forms found grew on the Tamarack; they often grow singly, and then again together, one above the other. One individual measured 4 inches (10 ^{cm}) in width laterally, 2.8 inches (7 ^{cm}) from front to back, and 2 inches (5 ^{cm}) in thickness at the back along the bark (Pl. XII, fig. 2). The pores in the Tamarack specimens are exceedingly regular, far more so than in those of any of the other sporophores.

The sporophores of *Trametes pini* forma *abietis* grow both on living and fallen trees. They were found on trees which had been cut down four years before, and new ones were constantly appearing. It is this faculty of fruiting on dead trees that must enable this fungus to spread through a forest in a very short time, and accounts for the fact that it does so. After a Spruce has reached a certain age the chances that it will become affected with this parasite are, in the Maine woods, the very greatest. Older trees, i. e., Spruces which have reached a diameter of 10 to 12 inches, are more often subject to attack than younger ones. The fungus enters through any wound, and apparently spreads rapidly. There is no evidence at present to

show how rapidly it spreads, nor whether the characteristic form of decay which it induces continues in wood after it has been cut from a tree or not. The present view seems to indicate that it does not grow after the death of the tree.

HYMENIUM.

Hartig[1] has given a very full description and numerous drawings of the hymenial layer of this fungus, and his observations can simply be confirmed. The basidia arise as slender hyphæ, which gradually become much smaller at the apex and form four slender, rather long sterigmata, bearing the spores. These are colorless at first, but turn brown later on, and not infrequently contain an oil globule in the center. The most striking elements of the hymenial layer are the cystidia, called hairs by Hartig. They arise from internal hyphæ, which approach the hymenial layer at an angle. Pushing between the basidia and paraphyses one finds these large, pointed, brown, spine-like bodies, which project for a considerable distance into the pore canal (Pl. IX, figs. 2 and 3). They are thick walled and persist for a long time after the disappearance of the basidia and spores.

As the pores grow older they are filled with a network of hyphæ which grow out from the body of the sporophore, growing over the hymenial layer and completely plugging the hole. The exact period when this takes place was not determined.

POLYPORUS SULFUREUS (Bull.) Fr.

OCCURRENCE.

This fungus, although more frequently found on the hardwood trees, occurs now and then on living Spruces and brings about a brown rot of the wood of trunk and branches. The trees found were attacked after the trunks were 9 inches (23^{cm}.) in diameter. Entrance is effected through wounds and broken branches, much in the same way as the other parasitic fungi which enter above the ground. The mycelium spreads through the trunk of an affected tree, growing up and down, and reaching the highest branches in one direction and the roots in the other. No evidence of a diseased condition is usually visible on the outside, except such as noted for the other diseases.

STRUCTURE OF DISEASED WOOD.

Diseased wood is red-brown in color and can readily be distinguished from wood changed by the other fungi described by the fact that it breaks into slabs or flat pieces, which correspond each to an annual ring of wood (Pl. XIII). The brown rotted wood is hard, very brittle,

[1] Hartig, R. Wichtige Krankheiten der Waldbäume. 50. *pl.* 3. 1874.

and breaks into more or less rectangular pieces. When in its final stages, it is exceedingly brittle and can be crushed to a fine powder in a mortar. It is always much firmer than wood destroyed by *Polyporus schweinitzii* and differs from the latter in the character of the cracks or breaks, which are most readily seen on a tangential view.

The progressive changes which take place in the wood of a Spruce may be noted as follows: The wood at first turns slightly red-brown in irregular patches, as seen when a trunk is split longitudinally. These patches grow larger, spreading from ring to ring and in a longitudinal direction along each ring. Small cracks next appear in these areas, extending part way through the thickness of each ring, both from the side of the spring and of the summer wood. These cracks are very much more visible on the tangential view of an annual ring (Pl. XI, fig. 1). At first but scattered cracks are to be seen extending longitudinally, which, however, soon elongate and pass both diagonally and directly across the direction of the fibers (Pl. XI, fig. 4). At this stage the wood is still hard and has acquired a light-brown color. Immediately about the fissures it is more deeply colored than elsewhere. A microscopic examination shows that there has been great shrinkage in the volume of the cell walls and that the breaks and fissures occur practically throughout the whole mass of the brown wood; though only the larger breaks are visible to the unaided eye. The shrinkage goes on rapidly, and after a time the tension becomes so great that the annual rings separate one from the other. A break usually occurs in a radial direction also, and as a result the free ends of the ring swing outward. Breaks along the lines of the larger medullary rays take place at the same time. This gives rise to long flat slabs of wood, each the width of an annual ring, which hang together loosely at one end and at isolated points on their tangential walls (Pl. XIII). Very badly decayed wood is so thoroughly traversed by larger and smaller breaks that it readily falls to pieces when struck. It must be noted, however, that the nature of the cracks is such that individual pieces of wood are, as it were, mortised into each other end to end, and this no doubt makes the wood as firm as it is.

MINUTE CHANGES IN THE WOOD.

The minute changes which the mycelium of *Polyporus sulfureus* induces in the wood cells are such that they can not well be mistaken. It has been mentioned that the annual rings break into bands which curve inward as the process of drying goes on. A tangential view of several of these bands before they have broken will present an appearance such as is shown on Pl. XI, fig. 4. A large number of fissures have formed both across the wood fibers and parallel with them. The latter are more prominent—the cross fissures never occurring alone, but generally connecting several longitudinal fissures. It will be noted that the breaks are

characterized by sharp right angles, and in many places a stepladder arrangement is evident. In the early stages of attack the wood fibers turn red-brown and shrink. As a result, fissures are formed in the walls of the tracheids, which extend diagonally across the wall at an angle of approximately 45 degrees (Pl. XI, fig. 1). The medullary ray cells are at this period still intact, and hold together the more or less brittle wood fibers. The next stage in the decomposition consists in the absorption of the medullary rays. This allows the wood fibers to contract more than up to that time, and as a result breaks occur. These breaks form at first so as to connect adjacent cavities left by the absorption of the medullary rays. The wood fibers tend to curve in one direction or another and break at the weakest point, namely, between two cavities, where the opportunity for curvature is greatest. What determines the direction of curvature of the wood fibers has not yet been explained. In the illustration the curvature is toward the right. This curving has the effect of bringing medullary rays which are in different longitudinal rows approximately into a line. Thus at "*a*" two cavities are shown which are separated by a curved fiber which sooner or later will break, uniting the two. At first two ray cavities are joined, then more, until long longitudinal holes are formed, such as are shown in fig. 4 of Pl. XI. The reason for the sharp angles is now very apparent, likewise why these fissure figures appear only on a tangential view while on the radial view one simply sees the fissures as lines extending at right angles across a ring of wood (Pl. XIII).

The marking of the individual wood cells is a very regular one. The fissures extend through the secondary lamella, and at first sight remind one of those which the mycelium of *Polyporus schweinitzii* induces. The latter are very much steeper, however, and do not occur at such frequent intervals.

The mycelium of *Polyporus sulfureus* is colorless and is present only here and there in the wood cells, a fact to which Hartig calls attention. No spores, such as are so common when this fungus grows in Oak wood, were seen in the Spruce wood, although diligent search was made for them.

FRUITING ORGAN.

The sporophores of *Polyporus sulfureus* are among the commonest and best known of the largest fungi. The sulphur-yellow shelves of this fungus occur widely distributed throughout the United States, and are found in late August and September on many of the Oaks, Walnut, and other broad-leaf trees. A large number of sporophores usually appear together, one above the other, when growing from an upright trunk, or scattered here or there on a prostrate log. They grow on living trees and on the dead trunks also, for several years after the latter have fallen. A marked periodicity in this respect

was noted for a particular tree during the past summer. This tree, a large White Spruce, had been blown down some years when first seen. The standing stump was 12 feet (3⅝ meters) in height, and on its south side there developed in August of 1897 a large number of the sporophores. These dried and broke away during the following winter. During the summer of 1898 no sporophores appeared on either the standing stump or the fallen log, and it was not until August, 1899, that a new lot of the brackets appeared, and then in the greatest number. Three large patches broke out on the north and northwest side of the trunk, and the lower side of the fallen log was literally covered with the yellow brackets. No mention of this periodical occurrence of the fruiting portion has been found, and it will be of considerable interest to see what will take place this year. Several other large Spruces in the immediate neighborhood were caused to decay by this fungus, but no sporophores have so far developed on their trunks.

The shape of the pileus varies materially with the position which it happens to occupy. When on upright trunks several sessile sporophores usually occur one above the other, the upper surfaces of the lower ones touching and uniting here and there with the lower surfaces of those above. The individual parts are comparatively thin plates, which have radiating lines and depressions extending outward to the margin. The body of each is soft and fleshy when young and full of a clear yellowish liquid. The upper surface when young is very moist, somewhat hairy, and when bruised turns brown. As the plant grows older it becomes very much harder, and when completely formed is quite hard and brittle. Masses of the young plants have a peculiar fungous odor, which becomes very intense as the parts grow older. The lower surface of the shelf is smooth and even. The pores are formed very early in its development, and almost as soon as they are completed the formation and discharge of spores begin. The sporophores are very short-lived. They begin to appear on the trunk as small rounded knobs, formed by thick-walled hyphæ, which come out from between the bark scales. Their growth is very rapid, even more so than that noted for *Polyporus schweinitzii*. The various small knobs soon flatten into a number of plates, consisting of strands of hyphæ, some of which grow out horizontally, increasing the width of the pileus, while others grow downward to form the pores. When the sporophores develop on the under side of a log they grow out in all directions from a central point, and sometimes forms with a distinct stipe are met with.

Numerous drops of the clear liquid mentioned before were found hanging from the under surface of the shelves on some days.[1] The appearance of the drops does not seem to stand in any relation to the amount of moisture in the air, for they were found alike on very dry

[1] Fries notes this fact—Epicrisis, etc. 450.

and very foggy days. The same sugar, melezitose, that was found in *Polyporus schweinitzii* was obtained from the liquid in quantity. The fungus is attacked when barely mature by insects and small animals, and within a month after the ripening of the spores there is little of it left except the harder upper surface of the shelves and the contracted basal portion. This may account for the fact that the spores ripen and are discharged so very rapidly. Cultures of spores made in water, in sugar water, and on bread showed no signs of germination. These experiments are to be repeated with better cultural facilities.

The spores spread through the air and are carried to all parts of the forest. Wherever any wound or broken branch offers suitable conditions they germinate and induce the rot described.

Polyporus sulfureus was found only on trees growing along the coast of Maine. They were all older trees of the White Spruce. Further search will no doubt show that it attacks the Red Spruce also, and possibly the other conifers. Its large, conspicuous sporophores make its recognition easy, and the fact that they are edible in their early stages ought to lead to their collection and destruction.

POLYPORUS SUBACIDUS Peck.

Poria subacida Peck, Thirty-eighth Report N. Y. State Museum. 92.

OCCURRENCE.

There are a number of fungi which attack standing trees and destroy their wood, of which it is not possible to tell, without continuous observation and experimentation, to what extent they are responsible for the death of trees, and whether they attack perfectly healthy trees. Among these belongs the fungus which for the present will be considered as *Polyporus subacidus* Pk. It is one which is found on decaying logs of coniferous as well as other woods,[1] forming its pores in late summer and winter. It was found once on a living Hemlock, twice on living White Spruce, and once within the trunk of a living White Pine. In many of the spruce forests hundreds of trees, particularly the younger ones, were found dead or dying. Many of these trees were pulled up, and on their roots yellowish masses of mycelium were occasionally found. In one locality some thirty of these young trees, ranging from 2 to 10 inches (5 to 25 cm.) in diameter, had the wood of the trunk decayed by some fungus. The wood appeared yellow, was very wet and spongy, and was easily pulled into shreds. No fruiting organs could be found. Several of the trunks were taken and sawed into pieces a foot (30 cm.) or more in length. These pieces were buried to the depth of a foot (30 cm.) in a sphagnum bank and were examined every week. Other trees were simply broken near the

[1] See Exsiccati, E. & E., N. A. Fungi.

ground and left standing, while in still others wounds were made with an axe to permit the entrance of air, as it was thought that fructification might thus be induced. After two weeks the ends of the pieces buried in sphagnum were covered with a white film of hyphæ, which gradually turned yellow, and after two months began to form shallow pores. The same took place in practically every one of the trees which were overturned or wounded. In all the localities visited where trees, both older and younger, had been overturned, this fungus was found again and again, and associated with it the form of wood decay described below. (Pls. XIV and XV.)

Masses of yellowish mycelium were sometimes found growing out from under the bark scales of the roots of many healthy spruces in a way which seemed to indicate that they were beginning to enter the root itself. Hyphæ from these masses extend into the soil, binding together the particles so that dense clumps are formed, varying from the size of a pea to as large as two fists put together. The growth of the hyphæ in the soil is a very rapid one; they can be grown with ease in moist soil and form the peculiar lumps in a few weeks. Pieces of diseased trunks were buried in soil in a greenhouse in September, and in four months the hyphæ had grown through the soil of the bench in all directions. It is thus very evident that this fungus grows in the ground rapidly and that this is probably one of the ways in which it enters standing trees. This is made more probable by the fact that one finds all of the trees in a certain area affected with this fungus, both younger and older ones. Each probably infected its neighbor much in the way in which *Polyporus schweinitzii* does. The fruiting portion of the fungus has been found on living White Pine, Red and White Spruce, Fir, and Hemlock. A large Hemlock, almost 2 feet (0.6 meter) in diameter (near Houlton, Me.), had been blown over and the trunk had broken some 6 feet (2 meters) from the ground. The wood was very soft and showed numerous black spots surrounded by white areas. The fruiting organs were forming in the chinks and crevices of the trunk, and on the stump. The tree was alive at the time it was seen.

STRUCTURE OF DISEASED WOOD.

The decay which the mycelium of this fungus induces is not to be confused with that caused by any other fungus. Spruce wood when very much decayed is moist, almost wet at times, and can be compressed much like a sponge, when quantities of water will drip from the mass. Larger and smaller cavities of very irregular shapes, lined with a tough felt of hyphæ, yellow on the inner side, are found throughout the wood. Such a cavity is shown in part at the bottom of Pl. XIV, fig. 2. The cavities are scattered throughout the wood in most trees and are generally partially filled with a pale straw-colored liquid. The wood

itself differs markedly in different trees. This difference appears to be due somewhat to the rapidity with which the solution of the fibers takes place. As a rule, the wood in the early stages of the attack has numerous black spots scattered throughout its mass (Pl. XIV, fig. 1). These black spots are surrounded by a white circle before long, and somewhat later disappear entirely, leaving very much larger white spots. The wood around the spots is now straw-yellow in color and begins to look somewhat frayed, as if groups of wood fibers were separating readily from the rest. A tendency for the different annual rings to separate now becomes very marked (Pl. XIV, fig. 1, at the right), and a log of spruce wood at this stage can be split into concentric rings by mere pounding. Gradually the number of white spots increases. In one form of decay the white spots are confined almost entirely to the summer wood. The newly formed spots are also in the summer wood, and before very long all the summer wood of every ring, including also some of the adjacent spring wood of that ring, has turned white. This stage of decomposition is shown very well in Pl. XIV, fig. 2, a longitudinal section of a spruce log, and in Pl. XV, fig. 1, a cross section of the same log. It will be noted that the change to the white masses nowhere passes from the summer wood of one ring to the spring wood of the adjoining ring. There is evidently some agent, presumably of a chemical nature, which confines the solvent action of the fungus mycelium to the summer wood and prevents it from attacking the spring wood. It may be recalled here that where a similar change takes place in the spruce wood, induced by the mycelium of *Trametes pini* forma *abietis* (Pl. X, fig. 2) both summer and spring wood were changed. This localized action of the dissolving agent takes place with such regularity and in so many different ways, depending upon the kind of fungus attacking the wood, that it suggests the presence of specifically distinct dissolving agents, enzymes, perchance, for each fungus.

In the second form of decay the appearance of the white spots is limited to the summer wood in the same way as above described. The white spots do not increase in number so rapidly and consequently do not form the white bands spoken of. Changes take place within the wood cells of the spring wood, which give to them a very light and porous nature. A cubic inch (16.4^{cc}) of such wood completely decayed weighs but 1.3 grams (sound spruce wood weighs 5.52 grams).

The mycelium of the fungus spreads through the individual tracheids after entering the tree, and collects in spots here and there. Solution of the wood cells begins around these centers, which at this time appear dark brown or black. They are the black spots referred to above. The change which takes place around these centers consists in a solution of the hadromal and the other lignin constituents of the cell walls, leaving the pure cellulose fibers free from one another. These con-

stitute the white spots and also the white bands spoken of. The various steps leading to the complete separation of the cellulose fibers are exactly those which have been described for a similar process caused by the hyphæ of *Trametes pini* forma *abietis*.

A very different change is going on at the same time in the spring wood, and gradually spreads from this to the summer wood. This change may be likened to the one which Hartig has described as taking place in pine wood attacked by *Polyporus borealis*.[1] The hyphæ of the fungus develop in the wood cells with great rapidity, filling them completely. Numerous hyphæ pass through the walls in all directions, making large irregular holes many times the diameter of the hyphæ which pass through them. The secondary walls of the wood cells are gradually dissolved; a faint granular appearance of the walls is seen at first, and little by little the walls become thinner. At last only the primary lamella is left, and in the bordered pits the torus (Pl. XI, fig. 3). The whole wall finally disappears, leaving simply that part of the wall belonging to two or three cells, namely, the portion having a triangular cross section. This solution of the walls goes on simultaneously throughout large areas. The medullary rays disappear completely, long before the wood cells are entirely gone. The spaces left by the dissolved cells are rapidly filled with hyphæ and these hold portions of the cell walls not yet destroyed in place, and give consistency to the mass, which thus retains the shape of the wood before the attack. The whole mass can be compressed by slight pressure and will not return to its original size. This accounts for the extremely light weight of wood thus decayed. In Pl. XI, fig. 2, a radial view of wood in an advanced stage of decay is shown. The straight black lines indicate groups of wood vessels, two or more; the hyphæ between

FIG. 3.—Base of spruce branch, showing its resistance to the attack of the mycelium of *Polyporus subacidus* Pk.

[1] Hartig, R. Zersetzungserscheinungen des Holzes, etc.

them have dissolved out the missing fibers and now fill the spaces. Plate XI, fig. 3, represents a cross section of similarly attacked spruce wood, showing several wood fibers of the spring wood at one side and the gradual dissolution of adjoining ones, leaving only the more resistant portions which lie free in the masses of hyphæ. These remaining parts stain with phloroglucin and hydrochloric acid, showing that they are still lignified walls. Heartwood and sapwood of the spruce are destroyed with equal rapidity. All parts become spongy, with the exception of the resinous basal pieces of the branches, which resist the attack of the fungus even after the whole trunk has been destroyed. This resistance of the basal pieces of the branches is quite a common feature in diseased trees attacked by several other fungi, notably *Polyporus schweinitzii*, but nowhere is it more striking than in this instance. Text figure 3 shows such a branch piece as it appeared immediately after pulling it from a dead standing tree.

FRUITING ORGAN.

After the mycelium has invaded the sapwood it grows out over the bark, forming yellow felts. This takes place in the early part of the summer, generally about July. A few weeks later the small pores begin to form. Certain hyphæ of the sheet turn at right angles to it and grow out at this angle, forming shallow pores. These are almost round and are separated by very thin dissepiments. Fig. 2, Pl. XV, is from a photograph of a spruce log, about the middle of September, almost natural size. As the season progresses the fungus dies and splits up into smaller areas and some of the tubes become inclined. No pores occur at the edge of the sheet, thus leaving a fringe of sterile hyphæ. This distinguishes this fungus from many allied forms. The hymenial layer and the pores are generally straw yellow, sometimes even more decidedly yellow, the color deepening toward the latter part of the fall. The pores do not form until December or January, and as a completely fruited fungus was collected but once, its description will be deferred until more material has been seen.

The fruiting organ frequently develops in cracks and breaks formed when a diseased tree is blown over. Fructification was induced in many instances, as described above, by allowing the air and moisture to have access to completely decayed wood.

When *Polyporus subacidus* grows in Northern forests on dead coniferous wood as a saprophyte, its habit and action differs somewhat from that described above. Inoculation experiments were made during the summer to test how rapidly this fungus destroys sound wood. Diseased wood from both dead and living trees was placed in holes bored in healthy spruces, and the latter were labeled so as to be readily identified in later years. The amount of destruction which this fungus does

in the spruce forests is very large, but careful experiments will have to be made to determine its relation to trees weakened by other causes, also its progress through the soil from tree to tree.

REMEDIES.

This fungus may be accounted most destructive to dead timber, and any remedies spoken of for *Polyporus pinicola* apply here. Dead trees should be utilized before the chance for infection becomes too great. No practical remedies can be suggested at present to prevent its spread through the soil.

OTHER DISEASES.

Besides the diseases described in the foregoing there are a number of others of which not enough was seen to enable a full description to be given.

POLYPORUS VAPORARIUS (PERS.) FR.

This is frequent on Spruces and Firs, and induces a brown rot of the sapwood. The fungus occurs widely spread over the United States and Canada on all coniferous woods. Its fruiting body is very variable, and there are probably many fungi included under this name which do not belong there. From observations made in the Maine woods it seems that this fungus attacks dead much more than living trees, destroying them for timber very rapidly. A fuller description of it will be given at a later date.

POLYPORUS ANNOSUS FR.

This fungus is a parasite of European trees much feared by the foresters of the Continent. Diligent search was made for it, but fully formed fruiting bodies were not found. A single Spruce seen on the top of Mount Kineo, Moosehead Lake, had its roots covered with firm leathery sheets, such as *Polyporus annosus* sometimes forms on the roots of the Southern Pines. Unfortunately there were no means at hand to cut down the tree, so that an inspection of its trunk was impossible. Other diseased trees of Spruce and of the Fir were seen north of the Rangeley Lakes. One of these was overturned, having grown in a damp locality. Its roots were covered with the yellowish leathery felts which extended into the surrounding soil. The trunk of this tree was completely rotted in the center, the decay going up the trunk for 25 feet (almost 8 meters). At this point the wood was brown, showed some white areas, and smelled strongly of prussic acid. The stumps of many other Spruces were examined for evidences of this fungus. Some Spruces were found which had small holes in the summer wood of many annual rings. The wood when cut longitudinally showed many of these holes, which differed from those formed by *Trametes pini.*

They occurred chiefly in the summer wood, and were filled with a red-brown powder. There is no white lining as in the wood attacked by *Trametes pini*. Black spots appear here and there in the wood, and when they disappear the holes take their place. The holes increase in size and number, and in the last stages of decomposition the wood has become a shredded mass of yellow-brown fibers, which feel much like straw. It is completely honeycombed in every direction. The annual rings of wood separate from one another, forming thin plates perforated by thousands of small holes. The transformation of this fibrous material takes place from the root up into the trunk for from 3 to 20 feet (1 to 6 meters). In some trees the innermost rings of wood are affected. As the wood becomes more and more rotted a hole is formed which gradually increases in diameter, eventually sometimes becoming so large that the weakened trunk is blown over by the wind. On other trees one or the other side of the trunk may be affected. Two or more separate holes may be formed which join near the base of the tree.

A more lengthy description of the changes in the wood just described is not deemed necessary, in view of the fact that the active agent which brings about the changes is as yet not fully determined. If it proves to be *Polyporus annosus* Fr. it would seem that the injury done in the Eastern forests by this fungus is not very large, which may be considered a fortunate circumstance, as this fungus is one naturally to be dreaded by the forester, as it is combated only with the greatest difficulty and expense.

AGARICUS MELLEUS VAHL.

Many trees were found in which the well-known rhizomorph strands of this fungus grew under the bark. The summer of 1899 was exceedingly dry, and on that account the development of Agaricineæ of all kinds was a very meager one. On the various excursions made through the Maine forests but one tree was found on which the yellow fruiting organ of this fungus was developing. The manner in which this fungus grows on the roots of the trees and brings about their death has been so fully described by Hartig and others that it seems hardly necessary to describe it here. The fungus grows within the living roots and cambium of a tree and speedily brings about a disturbance in its absorbing organs which results in ultimate death. The wood is rarely if ever affected to any extent, so that lumbermen use the diseased trees for lumbering purposes, making no distinction between them and live trees as long as the wood is entirely sound. Diseased trees should be cut at once when recognized.

CONCLUSION.

The conditions in the New England forests are very favorable to the growth and development of timber-destroying fungi, conditions which are made still more favorable by an ever increasing supply of dead wood. Radical changes will be necessary in the present lumbering methods in certain localities before any betterment can be hoped for. During the summer of 1899 the wasteful cutting of timber was noticed in particular in the region north of the Moosehead Lake, where the old system of measuring logs by the top scale is still in vogue. The lumberman cuts the logs on the stumpage plan, and in his endeavor to obtain as high a scale as possible he cuts the tree high up on the trunk and low in the top, leaving almost half the top in the woods. This is not only wasteful lumbering, but offers an excellent opportunity for the development of several of the fungi described in the foregoing pages. From the dead trunks and limbs their spores spread to standing trees which might otherwise remain sound. The same is true for the insects, as recently pointed out by Hopkins.[1]

In the foregoing it has been pointed out that as trees grow older they become more liable to insect and fungus attack. An old tree has many vulnerable points, such as old branches and wounds made by animals or by hail, where insects or fungi may gain entrance to begin their work of destruction.

As a tree grows older the chances that it will be attacked become greater. This point ought to be taken into consideration in the harvesting of a timber crop. In certain sections of the Maine forests, particularly in the Rangeley Lake region, the trees have reached an age where it appears that the rate of annual accretion, and consequently the annual increase in value, is very small, while the danger of infection is increasing every year. It is recommended that such trees be cut immediately where practicable, as they are practically ripe and probably at their point of greatest value. This may not always be possible, owing to practical difficulties in reaching water courses, etc., but the principle should be established that it will prove more profitable in the long run to cut trees after they have reached a certain age, to prevent depreciation due to the attack of fungi or insects. Future investigation will have to determine what the exact age is at which it will be most profitable to do this cutting.

It has also been pointed out that there are several fungi which attack trees after they have been killed by insects or other agents. This is of great practical significance, for it may often be possible to harvest such dead trees before the fungus in question has had time to begin its work.

[1] Hopkins, A. D. Preliminary Report on the Insect Enemies of the Forests of the Northwest. Bul. No. 21, Div. of Entomology, U. S. Dept. Agr. 1899.

In the Maine forests great areas of forest lands were killed by bark beetles some years ago. If the dead trees had been cut shortly after their death, the timber might have been utilized, and it would have been as valuable as that from live trees, for the beetles do not mine in the heartwood. This was not done, however, and before long the whole forest of dead trees was rendered worthless by several fungi, notably *Polyporus pinicola* and *Polyporus subacidus*. What is true of larger areas holds for individual trees in the forest, and also in those sections where strong winds blow over many trees. Such an area, technically known as a windfall, offers opportunities for the action of destructive fungi, and the same recommendations just made for areas where trees are destroyed by insects hold good. A dead tree is as valuable as a live tree, provided its wood is sound, and it ought to be cut immediately. There is some prejudice among lumber bosses that such trees are of no account; nothing can be further from the truth, and this fact ought to be insisted on by those in charge of cutting operations.

The trees, now in the forest, which are diseased are beyond help, and it is at present neither practicable nor economical to practice the methods in use by the European foresters, which consist in the prompt removal and destruction of the diseased trees. The time will come when this may prove profitable in the regenerated forests, but for the present the most hopeful method of combating fungi is by conservative lumbering. Men who are acquainted with the manner in which insects and fungi work and who can direct the cutting operations ought to be employed.

It may not be out of place here to refer to the growing sentiment in favor of restricted cutting, which was very much in evidence in the localities visited. Much agitation is still going on decrying the lumberman as the greatest enemy of the forest; but with the growing realization that it is possible to utilize the timber of the forest and still leave a forest which will yield timber from year to year, this feeling is gradually lessening. The lumberman has not been slow in realizing that restricted cutting will be more economical in the long run than the indiscriminate destruction of the past years. It is gratifying to note that two of the largest lumber owners of western Maine are employing trained foresters, under whose directions the cutting operations are carried on.[1] These men will not only be able to make operations more profitable, but can also aid in gathering information which may go to solve many of the problems still to be unraveled in connection with the enemies of forest trees.

[1] See also Graves, Henry S. The Practice of Forestry by Private Owners. Yearbook, Dept. of Agr. **1899**: 415. 1900.

EXPLANATION OF PLATES.

PLATE I.

FIG. 1. Sporophores of *Polyporus schweinitzii* Fr.

FIG. 2. A piece of the bark of Red Spruce with sporophores of *Polyporus volvatus* Peck growing from holes formed by a boring beetle, a species of *Dendroctonus*.

PLATE II.

Cross section ($\times\frac{3}{4}$) of the trunk of a living young Balsam Fir (*Abies balsamea* (L.) Mill.) at a point 4 feet (1.2 meter) from the ground. Decay, caused by *Polyporus schweinitzii* Fr., has shrunk the wood, producing a number of cracks and giving it a rough appearance. It is so nonresistant that the saw tore the fibers instead of cutting them. The large crack at the top, extending through the sapwood, was formed when the tree was cut down. A small sporophore of the fungus grew at the base of this tree.

PLATE III.

Radial view ($\times\frac{1}{2}$) of a log of White Spruce (*Picea canadensis* (L.) B. S. P.), showing an early stage of decay induced by the mycelium of *Polyporus pinicola* (Swartz) Fr. The fine parallel lines indicate the annual rings of wood. Here and there white spots with darker centers are seen; likewise long white lines parallel to the course of the wood fibers, and others near the center of the figure, which extend in an irregular manner across the direction of the fibers.

PLATE IV.

Radial view ($\times\frac{1}{2}$) of a log of White Spruce (*Picea canadensis* B. S. P.), showing an advanced stage of decay induced by mycelium of *Polyporus pinicola* (Swartz) Fr. The wood has cracked throughout. The white masses are sheets of mycelium. At the right of the figure two sporophores are shown—one just beginning to develop, the other about 1 year old. The sapwood has been partially destroyed by boring larvæ, whose tunnels are filled with sawdust.

PLATE V.

Three sporophores ($\times\frac{1}{2}$) of *Polyporus pinicola* (Swartz) Fr. The uppermost one is a young one. The one on the right is growing on a stump, and its lower surface is much eaten by insects. The one on the left is a very old sporophore, in which the ridged upper surface is very marked.

PLATE VI.

FIG. 1. Radial view of a piece of wood (natural size) of the Red Spruce (*Picea rubens* Sargent), showing an early stage of the decay induced by the mycelium of *Trametes pini* (Brot.) Fr. forma *abietis* Karsten. The white spots indicate where the wood has been changed so as to leave cellulose fibers. Small black lines are visible here and there.

FIG. 2. Radial view of Red Spruce log (natural size), showing advanced stage of the same decay. The number of white spots has increased. The decay rarely goes beyond this stage.

PLATE VII.

Radial view of a log of Balsam Fir (*Abies balsamea* (L.) Mill.), showing advanced stage of decay due to *Trametes pini* (Brot.) Fr. forma *abietis* Karsten.

PLATE VIII.

FIG. 1. Piece ($\times\frac{3}{4}$) of wood of tamarack or larch (*Larix laricina*), showing early stage of the decay caused by *Trametes pini* (Brot.) Fr. forma *abietis* Karst. Note how the annual rings separate at one end.

FIG. 2. Piece ($\times\frac{3}{4}$) of tamarack wood, showing an advanced stage of the same decay. The piece is composed of very little sound wood; the larger portion is cellulose.

PLATE IX.

FIG. 1. Radial view of two spruce tracheids, showing the manner in which cracks appear in the walls when such wood is destroyed by *Polyporus schweinitzii* Fr.

FIG. 2. A pore from the sporophore of *Trametes pini* (Brot.) Fr. forma *abietis* Karst., growing on *Abies balsamea*, showing numerous cystidia projecting from the hymenial layer.

FIG. 3. Enlarged view of a portion of the hymenial layer shown in fig. 2, showing cystidia with thick walls and several basidia with spores.

FIG. 4. View ($\times\frac{1}{2}$) of the lower surface of an old pileus of *Polyporus pinicola* (Swartz) Fr., of which a portion has died. This is shaded dark. Hyphæ from the living parts are forming a new layer, which is slowly covering the dead parts. The pores are indicated by the dots.

FIG. 5. Young sporophore (natural size) of *Polyporus pinicola*, cut in the middle to show arrangement of pores and top.

FIG. 6. Resupinate form (natural size) of pileus of the same fungus.

FIG. 7. Older pileus (natural size) of the same fungus, sectioned through the middle.

FIG. 8. Diagrammatic representation of a section through the pores of *Polyporus pinicola*. They are continuous from year to year. A firmer layer of hyphæ, incrusted with crystals of oxalate of lime, forms a line of demarcation between successive growth increments.

FIG. 9. Cross section of wood elements from summer wood of Spruce (*Picea rubens* Sarg.) attacked by *Trametes pini* forma *abietis*, showing how the fibers are gradually changed until only cellulose is left; "w," unchanged wood fibers; "b," the outermost lamellæ (unshaded) now consist only of cellulose; "c," more advanced stage; "e," the middle lamella is being converted into cellulose, and is finally absorbed, leaving only portions "p" free among the white cellulose fibers.

FIG. 10. Radial view of tracheids from wood of Spruce (*Picea canadensis* (Mill.) B. S. P.) attacked by *Trametes pini* forma *abietis*, in the region of a hole fringed by a black line. (See Pl. VI, fig. 2.) The tracheids are filled successively with hyphæ, which are incrusted with a brown material so as to completely plug the tracheid.

FIG. 11. Tracheid from wood of Spruce (*Picea canadensis* (Mill.) B. S. P.) during early stage of attack by *Trametes pini* forma *abietis*, showing hyphæ.

FIG. 12. Hymenial layer of *Polyporus pinicola* (Swartz) Fr.

FIG. 13. Radial view of white area from wood of Balsam fir (*Abies balsamea* (L.) Mill.) attacked by *Trametes pini* (Brot) Fr. forma *abietis* Karst., showing how the hyphæ gradually recede from a center, forming plugs in every wood element. The plugs are colored almost black by a brown product of decomposition.

PLATE X.

FIG. 1. Cross section of Spruce wood partially destroyed by mycelium of *Polyporus pinicola*. Large cavities and breaks which are filled with fine hyphæ are being formed in the wood. The summer wood is indicated by the parallel shading, the hyphæ by dots; "c," a small fissure enlarged in text figure 2. The lines at the left = 0.5^{mm}.

FIG. 2. Cross section of a piece of Spruce wood, showing early stage of destruction by *Trametes pini* forma *abietis*. Parallel lines of holes filled with cellulose fibers, here indicated by dots, appear in the wood. The black lines bounding the cavities simply indicate the limit of change of cellulose, for in reality there is no such sharp line of demarcation. The short line at the right equals about $\frac{1}{25}$ of an inch (1mm).

FIG. 3. Later stage of the same form of decay. The wood is now simply a network of narrow wood lamellæ separating larger and smaller holes. In these lamellæ black lines are shown, which represent plugs of brown hyphæ incrusted with decomposition products. (See Pl. IX, figs. 10 and 13.) Cellulose fibers and mycelium fill some of the cavities. The short line at the base equals about $\frac{1}{25}$ of an inch (1mm).

FIG. 4. Longisection of wood (Spruce), showing effects of destruction by hyphæ of *Polyporus pinicola*.

FIG. 5. Cross section of several wood cells, showing changes which take place in wood such as shown in fig. 4.

PLATE XI.

FIG. 1. Tangential view of Spruce wood destroyed by mycelium of *Polyporus sulfureus* (Bull) Fr.: "a" wood elements which have been curved, bringing two medullary rays into line; "e" part where a break occurred, uniting two medullary rays.

FIG. 2. Radial view of wood in last stage of decay, induced by mycelium of *Polyporus subacidus* Pk. The straight black lines represent one or more wood elements held in place by the hyphæ which are wound all around them. Remnants of medullary rays are to be seen here and there.

FIG. 3. Several cells from such a piece as is shown in fig. 2 (also Pl. XIV, fig. 3). Normal wood cells of the spring wood are shown at the left, and going toward the right various stages in the solution of the cell walls.

FIG. 4. Tangential view of a piece of Spruce wood destroyed by mycelium of *Polyporus sulfureus*, showing characteristic breaks in the wood, formed by the uniting of many medullary rays by cross breaks. (See fig. 1 of this plate.) The short line at the left is equal to 1mm.

PLATE XII.

Various forms of sporophores of *Trametes pini* forma *abietis*.

FIG. 1. On Balsam Fir.

FIG. 2. On Tamarack.

FIG. 3. On horizontal branch of Spruce.

FIG. 4. On bark of trunk of Spruce.

FIG. 5. At base of dead branch of Spruce.

FIG. 6. Semipileate form on Spruce.

FIG. 7. At base of dead branch of Spruce.

PLATE XIII.

Radial view of a block of White Spruce (*Picea canadensis* (Mill.) B. S. P.) partly destroyed by mycelium of *Polyporus sulfureus*. The darker spots at one side show where the wood turns brown and ultimately cracks. The manner in which the annual rings separate is indicated near the top of the figure.

PLATE XIV.

FIG. 1. Radial view of White Spruce (*Picea canadensis*), showing early stage of destruction by *Polyporus subacidus* Pk.

FIG. 2. Radial view of White Spruce log showing destruction of wood by mycelium of *Polyporus subacidus* Pk. The white lines show where the wood has been so

changed as to leave cellulose fibers. Near the bottom of the figure note a cavity lined with mycelium.

FIG. 3. Radial view of White Spruce wood decayed still further by the same fungus. The wood is soft and flaky and is being changed to cellulose here and there.

PLATE XV.

FIG. 1. End view of a Spruce log similar to the one shown on Plate XIV, fig. 1, showing how the summer wood of every annual ring has been changed, leaving cellulose fibers.

FIG. 2. View (about natural size) of the resupinate sporophore of *Polyporus subacidus* Pk. on Spruce log, showing how it creeps over the bark.

O

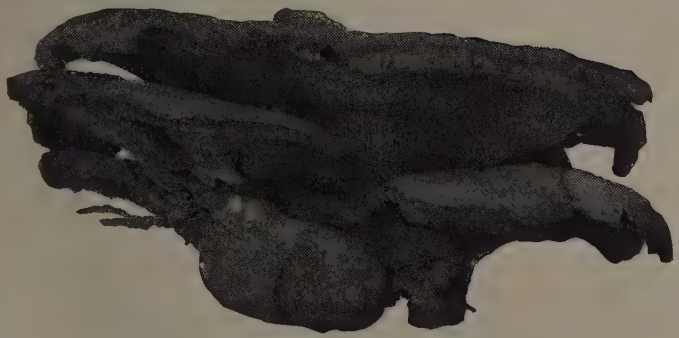


FIG. 1.—SPOROPHORES OF POLYPORUS SCHWEINITZII FR.

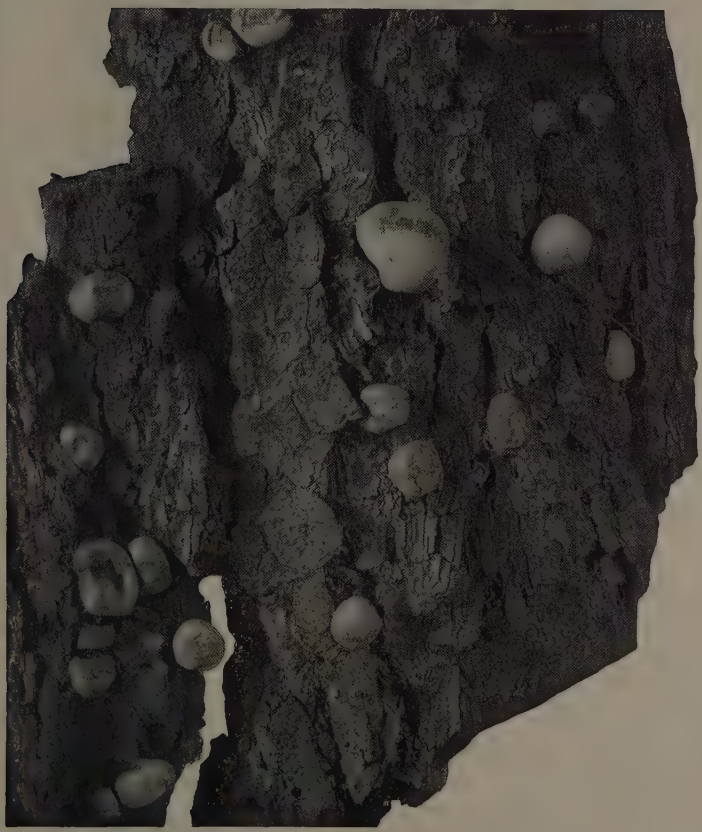


FIG. 2.—POLYPORUS VOLVATUS PECK, GROWING FROM HOLES MADE IN THE BARK BY DENDROCTONUS SP.

LOG OF BALSAM FIR SHOWING DECAY CAUSED BY POLYPORUS SCHWEINITZII FR.

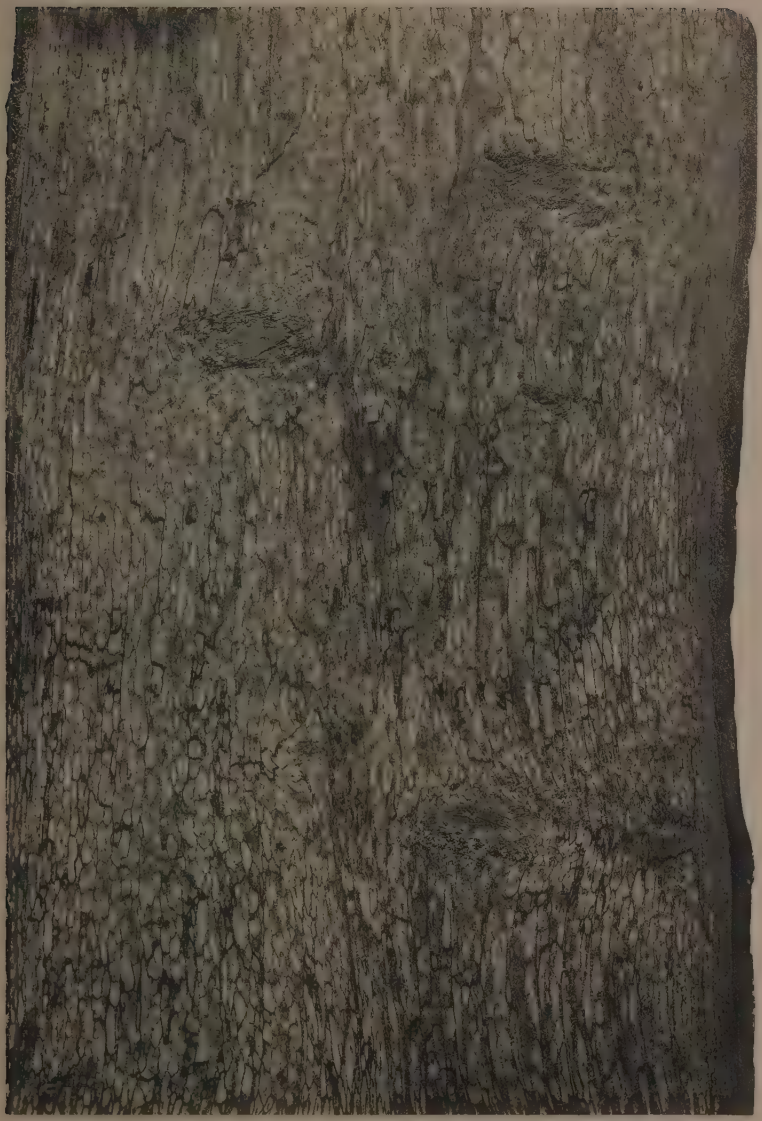
LOG OF WHITE SPRUCE SHOWING EARLY STAGE OF DECAY CAUSED BY POLYPORUS PINICOLA (SWARTZ) FR.

LOG OF WHITE SPRUCE SHOWING ADVANCED STAGE OF DECAY CAUSED BY POLYPORUS PINICOLA (SWARTZ) FR.

SPOROPHORES OF POLYPORUS PINICOLA (SWARTZ) FR.

FIG. 1. RED SPRUCE: EARLY STAGE OF THE DECAY CAUSED BY TRAMETES PINI FORMA ABIETIS

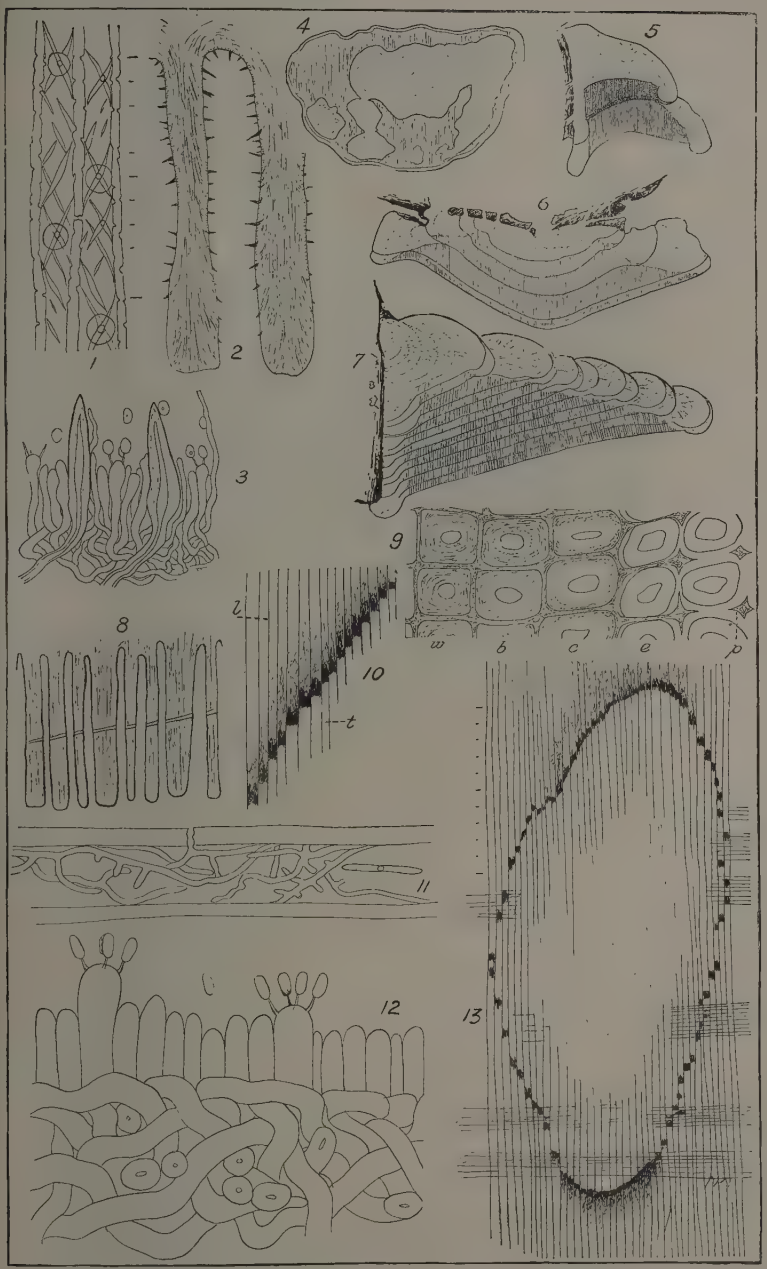
FIG 2. RED SPRUCE: ADVANCED STAGE OF THE DECAY CAUSED BY TRAMETES PINI FORMA ABIETIS.



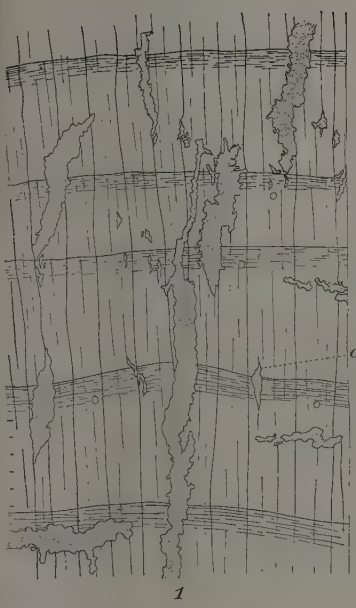
LOG OF BALSAM FIR SHOWING DECAY CAUSED BY TRAMETES PINI FORMA ABIETIS.

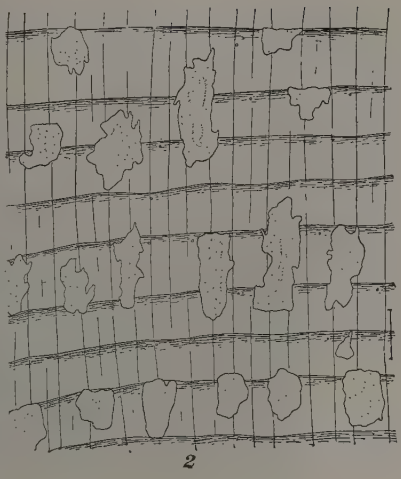
FIG. 1. FIG. 2.

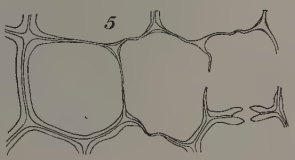
FIG. 1 EARLY STAGE AND FIG. 2 LATE STAGE OF DECAY OF LARCH CAUSED BY TRAMETES PINI FORMA ABIETIS

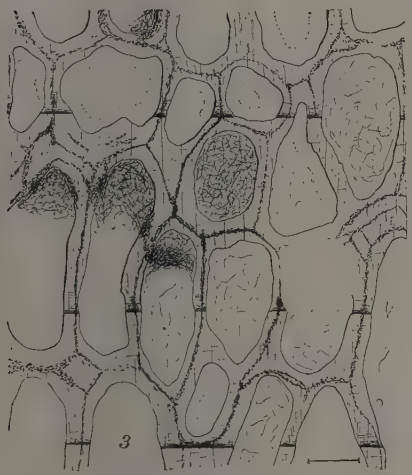


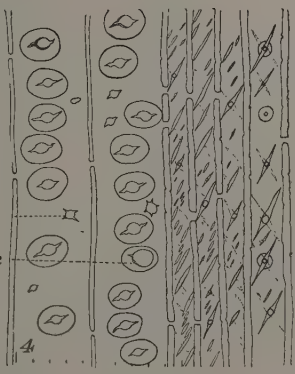
POLYPORUS SUBACIDUS PK., POLYPORUS PINICOLA (SWARTZ) FR., AND TRAMETES PINI (BROT.) FR. FORMA ABIETIS KARST.



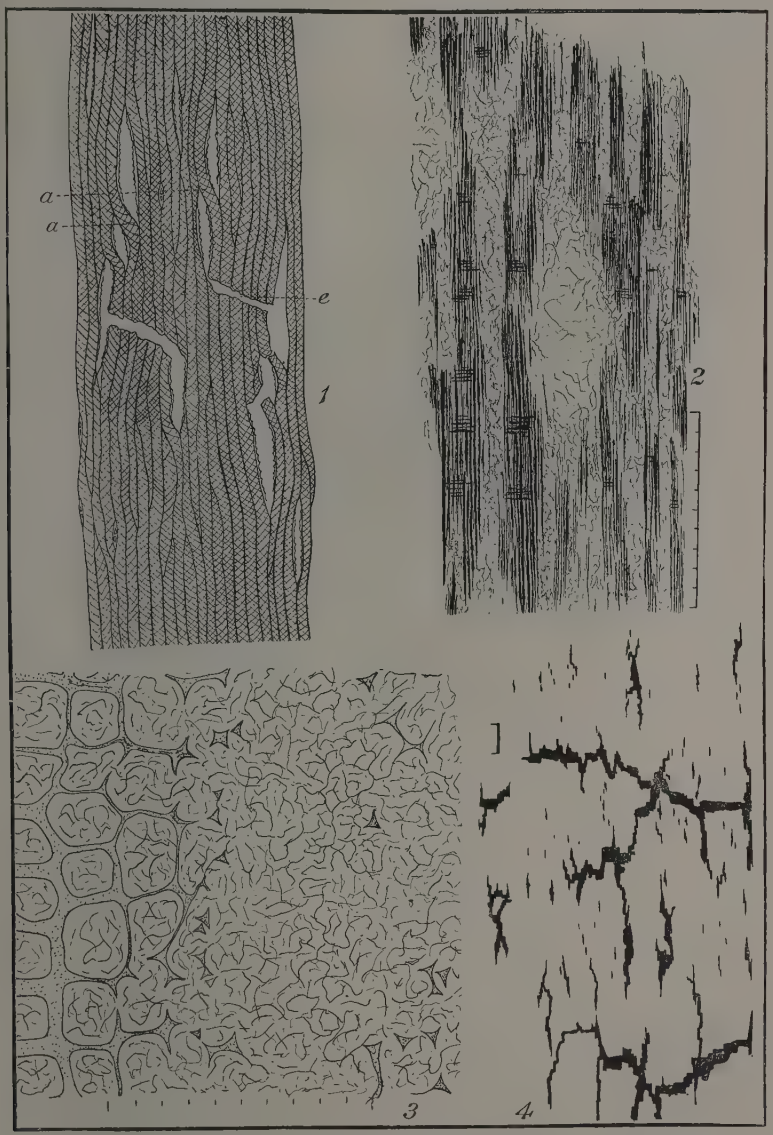




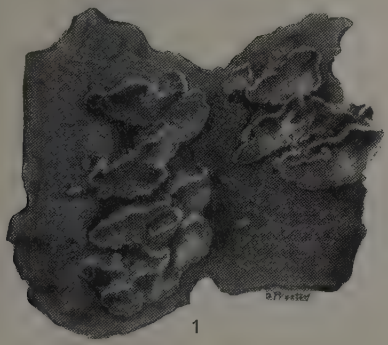




WORK OF POLYPORUS PINICOLA (SWARTZ) FR. AND TRAMETES PINI (BROT.) FR. FORMA ABIETIS KARST



STAGES OF DECAY INDUCED IN SPRUCE BY POLYPORUS SUBACIDUS PK. AND POLYPORUS SULFUREUS (BULL.) FR.



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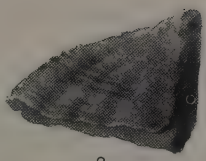

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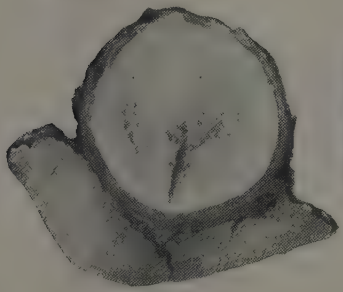

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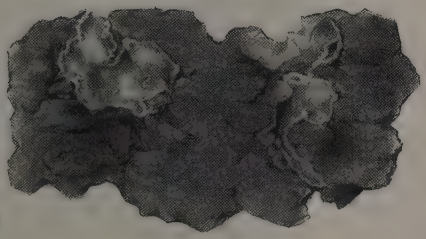

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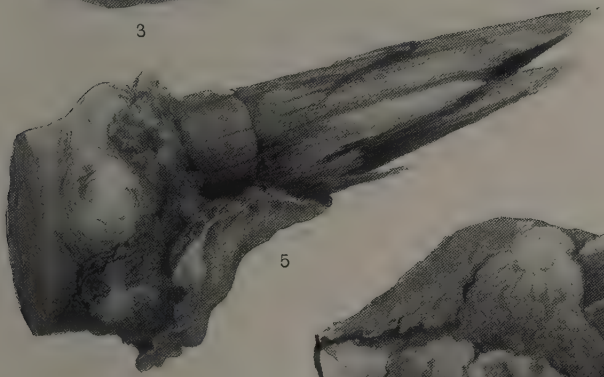

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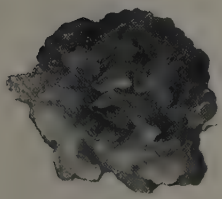

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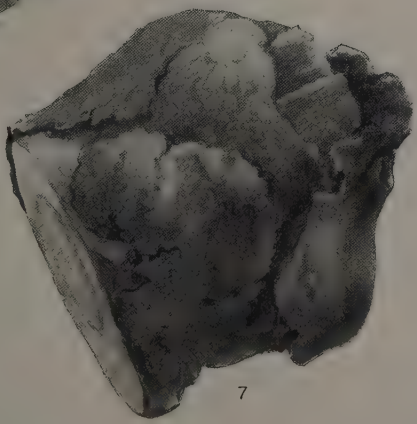
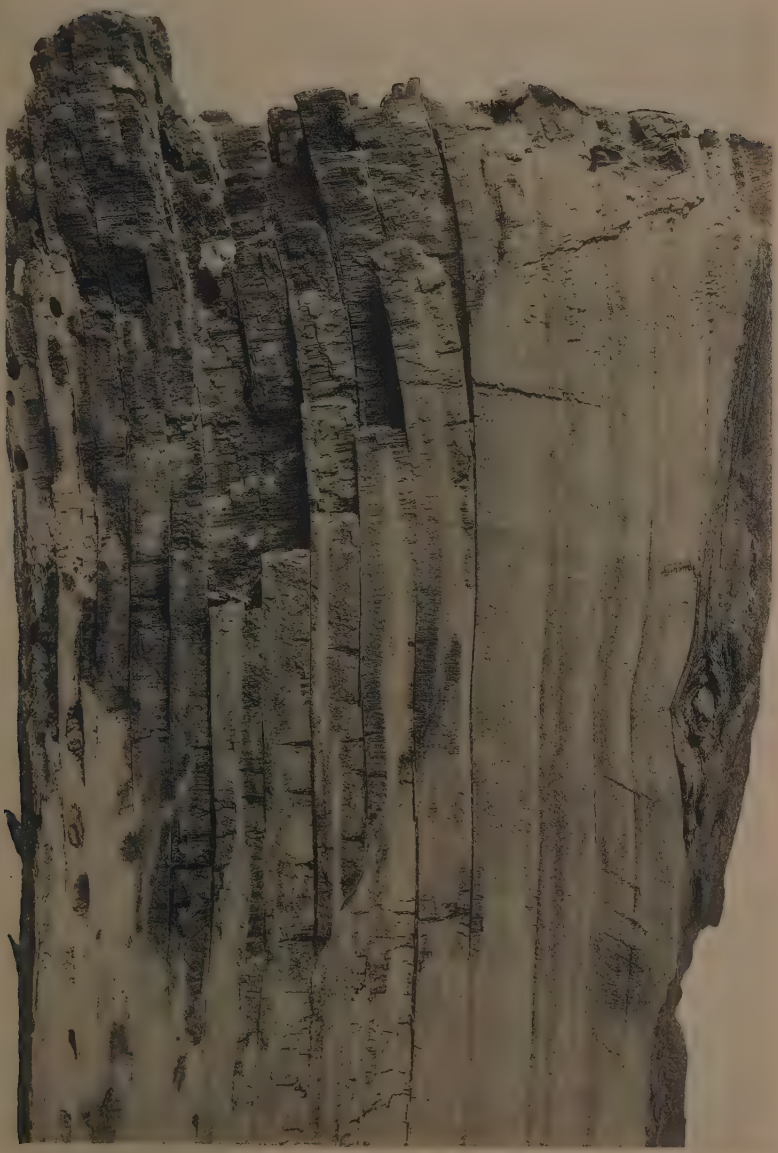


7

VARIOUS FORMS OF SPOROPHORES OF TRAMETES PINI (BROT.) FR. FORMA ABIETIS KARST.



BLOCK OF WHITE SPRUCE WOOD SHOWING INJURY CAUSED BY POLYPORUS SULFUREUS.

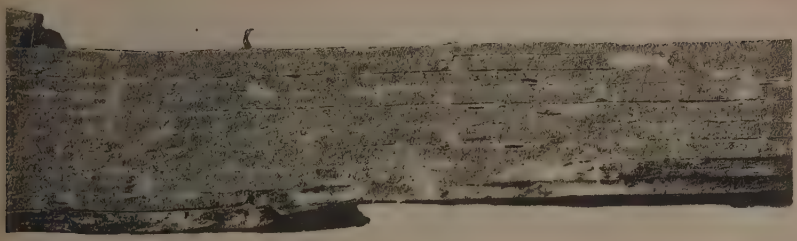


FIG. 1.

FIG. 2.

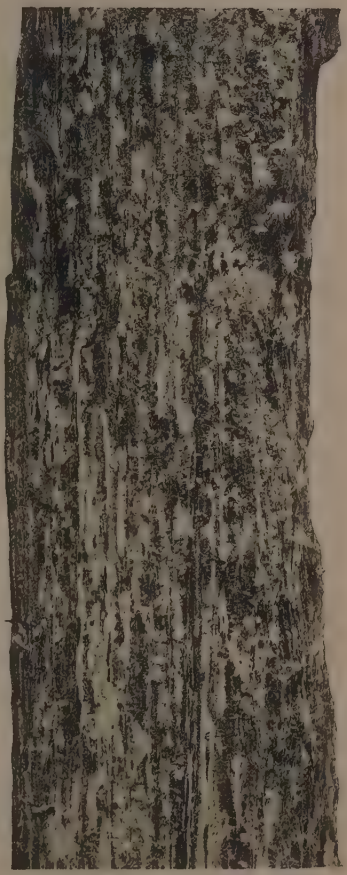


FIG. 3.

FIG. 1 EARLY STAGE AND FIGS. 2 AND 3 SUCCESSIVELY LATER STAGES OF THE DECAY CAUSED IN WHITE SPRUCE BY POLYPORUS SUBACIDUS PECK.

FIG. 1. CROSS SECTION OF LOG OF SPRUCE SHOWING DECAY CAUSED BY POLYPORUS SUBACIDUS PECK.

FIG. 2. RESUPINATE FORM OF SPOROPHORE OF POLYPORUS SUBACIDUS PECK ON SPRUCE LOG.

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